CHRIS HANI DISTRICT MUNICIPALITY

AIR QUALITY MANAGEMENT PLAN

Draft Status Quo Report

2018

COMPILED BY

GONDWANA

ENVIRONMENTAL SOLUTIONS

DOCUMENT CONTROL	
CLIENT:	
CLIENT ADDRESS:	Chris Hani District Municipality, 15 Bels Road, Queenstown,5319
PROJECT NUMBER:	2018CHD-0457
REPORT NUMBER:	RN_1801318_CHD
REVISION NUMBER:	0
DATE SUBMITTED:	25 October 2018
COMPILED BY:	Robyn van Basten Elanie van Staden Martin van Nierop
CONTACT DETAILS:	Gondwana Environmental Solutions (Pty) Ltd 562 Ontdekkers Road, Florida, P.O Box 158, Florida Hills, 1716 Tel: +27 11 472 3112; Fax: +27 11 674 3705; E-mail: info@gesza.co.za Web: www.gondwanagroup.co.za
DISCLAIMER:	Copyright © Gondwana Environmental Solutions International (Pty) Ltd (Gondwana). Gondwana holds copyright to this document. No publication or dissemination of its contents is allowed without prior permission. By signing this report, Gondwana do not make any warranty, expressed or implied, concerning the content thereof. It is certified that the data presented is, to the best of our knowledge, a true copy of the specified record and for the times and places indicated thereon, as held on file at Gondwana. The user assumes the entire risk related to the use of this data. In no event, will Gondwana be liable to the user or to any third party for any direct, indirect, incidental, consequential, special or exemplary damages or profit resulting from any use or misuse of this data.

Table of Contents

Table of Figures

List of Tables

Table of Abbreviations

AEL	Atmospheric Emissions Licence
AQMP	Air Quality Management Plan
AQO	Air Quality Officer
C_6H_6	Benzene
CO	Carbon Monoxide
DAFF	Department of Forestry and Fisheries
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DEDEAT	Department of Economic Development, Environmental Affairs & Tourism of the Eastern Cape
DM	District Municipality
DoE	Department of Energy
DWS	Department of Water and Sanitation
EEA	European Environment Agency
EHP	Environmental Health Practitioner
EMEP	European Monitoring and Evaluation Programme
FAO	Food and Agriculture Organization of the United Nations
FSSA	Fertilizer Society of South Africa
GHG	Greenhouse Gas
HPA	Highveld Priority Area
IDP	Integrated Development Plans
IPCC	Intergovernmental Panel on Climate Change
LM	Local Municipality
MD	Magisterial District
NAAQS	National Ambient Air Quality Standards
NAEIS	National Atmospheric Emission Inventory System
NDCR	National Dust Control Regulations
NEM:AQA	National Environmental Air Quality Act
NFAQM	National Framework for Air Quality Management
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compound
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
O_3	Ozone
PM_{10}	particulate matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	particulate matter with an aerodynamic diameter of less than 2.5 µm
SAAQIS	South African Air Quality Information System
SO_2	Sulphur Dioxide
VOC	Volatile Organic Compound
WHO	World Health Association
WWTW	Wastewater Treatment Works

1. INTRODUCTION

The Chris Hani District Municipality (Chris Hani DM) is one of the six District Municipalities in the Eastern Cape Province. According to the Constitution of the Republic of South Africa (RSA, 1996), a District Municipality (or Category C Municipality) holds executive and legislative authority in an area with more than one municipality. CHDM is comprised of the Inxuba Yethemba, Enoch Mgijima, Intsika Yethu, Emalahleni, Engcobo and Sakhisizwe Local Municipalities. The 2016 Local Government elections saw the realignment of Municipalities in the District, decreasing the number of Local Municipalities from eight to six. A merger of three Municipalities (Tsolwana, Inkwanca and Lukanji) resulted in the formation of the new Enoch Mgijima Local Municipality. The administrative seat of Chris Hani DM is located in Queenstown.

Air quality in South Africa is governed under the National Environmental Management Air Quality Act, (NEM:AQA) (Act No. 39, 2005) and related legislation such as the National Ambient Air Quality Standards (NAAQS) (Government Notice No. 1210, 2009). The NEM:AQA (Section 15(2)) requires Municipalities to introduce Air Quality Management Plans (AQMPs) that seek to improve air quality, identify and address emissions that have a negative effect on human health. Municipalities are required to include an AQMP as part of their Integrated Development Plans (IDP).

The main objective of this project is to develop an AQMP for the Chris Hani DM, as per the requirements of the NEM:AQA 2004.

The main aims of the Chris Hani DM AQMP are

- to ensure sustainable implementation of air quality standards within the Chris Hani DM;
- to comply with the Bill of Rights as enshrined in the Constitution of South Africa (South Africa, 1996) of every citizen having the right to live in an environment that is not harmful to their health;
- to recommend the methodology and processes for the monitoring of pollution parameters consistent with national, provincial and local norms and standards;
- to evaluate the existing air quality monitoring system in the Municipality and make recommendations for an effective air quality monitoring programme;

- to review the protocol for data collection, processing, quality control and assurance;
- to review the protocol for interpretation and archiving of reports;
- to establish an emission inventory of the study area by identifying sources, quantifying pollution and capturing these in geographic information systems (GIS);
- to initiate an air pollution dispersion modelling system; and
- to ensure the provision of sustainable air quality management support and services to all stakeholders within the Chris Hani DM.

In order to meet these aims, the immediate objectives are

- to conduct a Status Quo Assessment to determine pollution sources, ambient concentrations and the potential for human health effects within the Chris Hani DM;
- to conduct a feasibility study to outline the strategies to address the current air quality situation and provide recommendations for air quality monitoring;
- to compile an AQMP for the Chris Hani DM.

An AQMP has been compiled for Eastern Cape Province (uMoya-NILU, 2013) to promote air quality practice within the region. This AQMP provides the framework for the development of an AQMP in the Chris Hani DM.

1.1. Geographic Overview

Located within the Eastern Cape Province, Chris Hani DM covers an area of approximately 36 756 km^2, and is bordered by the District Municipalities of Joe Gqabi, Pixley ka Seme, O. R Tambo, Sarah Baartman and Amathole (CHDM, 2017). Major towns within the District include Queenstown, Middelburg, Engcobo.

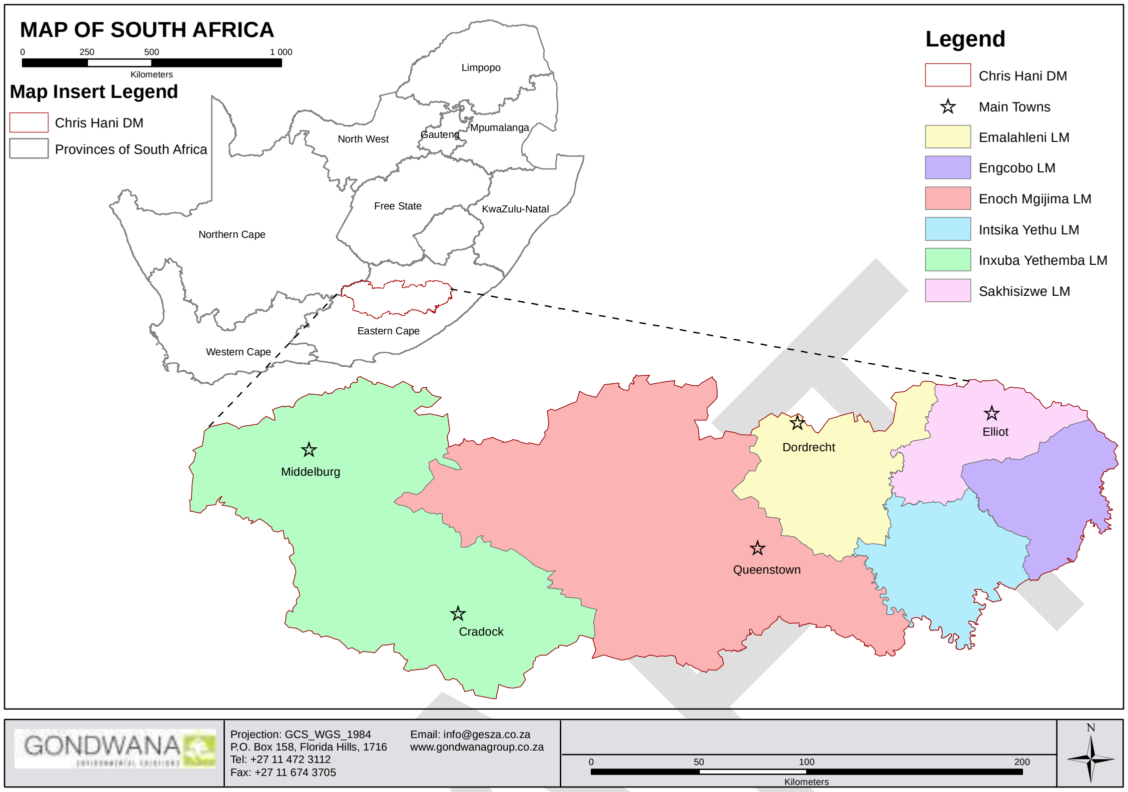

Figure 1: Location of Chris Hani District Municipality

Based on the 2016 Community Survey, the Chris Hani DM has a total population of approximately 830 495 (Table 1). Enoch Mgijima LM accounts for the largest part (31.70%) of the population in the Chris Hani DM, with a population of 263 263. Engcobo LM comprises 19.51% of the population within the Chris Hani DM, Intsika Yethu LM 17.62% and Emalahleni 14.77% (StatsSA, 2016).

Table 1: Population per Municipality in the Chris Hani District Municipality (StatsSA, 2016)

Municipality	Community Survey 2016	Percentage of Total Population (%)
Enoch Mgijima LM	263 263	31.70
Engcobo LM	162 014	19.51
Intsika Yethu LM	146 341	17.62
Emalahleni LM	122 691	14.77
Inxuba Yethemba LM	70 493	8.49
Sakhisizwe LM	65 693	7.91
Chris Hani DM	**830 495**	**100.00**

1.2. National Air Quality Management Planning

The NEM:AQA (Act No. 39, 2005) aims to provide reasonable measures to prevent air pollution and give effect to Section 24 of the Constitution (South Africa, 1996). The NEM:AQA of 2004 states that local authorities are required to develop AQMPs which should be in their Integrated Development Plans (Act No. 39, 2005). Section 15(2) of the Air Quality Act requires each Municipality to include an AQMP in its Integrated Development Plan (IDP) as required in terms of Chapter 5 of the Municipal Systems Act (Act No. 32, 2000).

The AQMP developed for the Chris Hani DM is in line with the AQMPs developed locally. The guidelines outlined in the 2007 National Framework for Air Quality Management in the Republic of South Africa (NFAQM) (Government Notice No. 1138, 2007) the 2012 reviewed National Framework for Air Quality Management in the Republic of South Africa (Government Notice No. 919, 2013) and the Air Quality Management Plan Guideline Documents (DEA, 2012) provided by the Department of Environmental Affairs (DEA) will also be followed.

1.3. Outline of Report

Section 2 describes the policy and legislative requirements with specific reference to air quality legislation and the NAAQS. Section 3 gives an overview of the criteria pollutants and the associated health and environmental impacts. Section 4 provides an overview of the prevailing meteorological conditions in the Chris Hani DM using surface meteorological data. Section 5 provides a brief overview of air pollution sources in the Chris Hani DM. Section 6 gives an overview of provincial and local government capacity and initiatives for air quality management. Emission reduction and management interventions are discussed in section 7 and section 8 provides the final recommendations and conclusion.

2. POLICY AND REGULATORY REQUIREMENTS

2.1. National Environmental Management: Air Quality Act 39 of 2004

The NEM:AQA shifted the approach of air quality management from solely source-based control to include receptor-based control as well. The main objectives of the Act are to:

- give effect to everyone's right to an environment that is not harmful to their health and well-being, and
- protect the environment by providing reasonable legislative and other measures that (i) prevent pollution and ecological degradation, (ii) promote conservation and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

The Act makes provision for the setting and formulation of National Ambient Air Quality Standards (NAAQS) for *'substances or mixtures of substances which present a threat to health, well-being or the environment'* (Act No. 39, 2005). More stringent standards can be established at the provincial and local levels. The control and management of emissions in the NEM:AQA relates to the listing of activities that are sources of emissions and the issuing of emission licenses.

Listed Activities are defined as "*activities which result in atmospheric emissions, which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage."* The South African Listed Activities were initially promulgated in 2010 (Government Notice No. 248, 2010), amended in 2013 (Government Notice No. 893, 2013) and further amended in 2015 (Government Notice No. 551, 2015). Any activity that falls within this list is required to have an Atmospheric Emissions License (AEL) to operate. Consequences of unlawful conduct of a Listed Activity are set out in the National Environmental Management: Air Quality Amendment Act (Act No. 20, 2014). The issuing of emission licenses for Listed Activities is the responsibility of the metropolitan and District Municipalities. Municipalities are required to *'designate an air quality officer to be responsible for coordinating matters pertaining to air quality management in the Municipality'* (Act No. 39, 2005). The appointed Air Quality Officer (AQO) will be responsible for the issuing of AELs. The current list of Listed Activities includes combustion installations, the petroleum industry (the production of gaseous and liquid fuels as well as petrochemicals from crude oil, coal, gas or biomass), carbonization and coal gasification, the metallurgical industry, mineral processing, the storage and handling organic chemicals industry, the inorganic chemicals industry, thermal treatment of hazardous and general waste, pulp and paper manufacturing activities (including by-products recovery), and animal matter processing.

Controlled Emitters were also introduced by NEM:AQA (Act No. 39, 2005). Controlled Emitters are defined as *"any appliance or activity, or any appliance or activity falling within a specified category…[which] result in atmospheric emissions which through ambient concentrations, bioaccumulation, deposition or in any other way present a threat to health or the environment or which the Minister or MEC reasonably believes presents such a threat"*. Once an appliance or activity has been declared as a Controlled Emitter, no person may manufacture, sell or use that appliance or conduct that activity unless it complies with the emission standards established for that appliance or activity. Small boilers were declared as Controlled Emitters in 2013 (Government Notice No. 831, 2013), temporary asphalt plants in 2014 (Government Notice No. 201, 2014), and small-scale char and small-scale charcoal plants in 2015 (Government Notice No. 602, 2015)

In addition, the minister may declare any substance contributing to air pollution to be a priority pollutant. Any industries or industrial sectors that emit these priority pollutants will be required to implement a Pollution Prevention Plan. Greenhouse gases have been declared as priority pollutants (Government Notice No. 172, 2014).

The NEM:AQA introduces the compulsory monitoring of ambient air quality. The national framework (NFAQM) legislates protocols, standards and methodologies for monitoring (Government Notice No. 1138, 2007; Government Notice No. 919, 2013). Comparison of the current state of air quality with the NAAQS (Government Notice No. 1210, 2009) can guide policy makers when making decisions that impact air quality.

The Act also requires relevant national departments, provinces and Municipalities to introduce Air Quality Management Plans (AQMPs) that set out what will be done to achieve the prescribed air quality standards. Metropolitan, District and Local Municipalities are required to include an AQMP as part of their Integrated Development Plan.

A summary of the functions and responsibilities of National, Provincial and Local Government, as informed by the NEM:AQA and the NFAQM are provided hereafter (Table 2).

Table 2: Air quality responsibilities and functions of National, Provincial and Local Government

National Government	Provincial Government	Local Government
Establish and review National Framework	None	None
Identify national priority pollutants	Identify provincial priority pollutants	Identify priority pollutants (through its by-laws)
Establish national air quality standards	Establish provincial air quality standards (more stringent)	Establish local air quality standards (most stringent)
Establish national emission standards	Establish provincial emission standards	Establish local emission standards
Appoint a National Air Quality Officer	Appoint a Provincial Air Quality Officer	Appoint an Air Quality Officer
Prepare a National AQMP as a component of their EIP	Prepare a Provincial AQMP as a component of their EIP	Develop an AQMP as part of their IDP
Execute overarching auditing function to ensure that adequate air quality monitoring occurs	Ambient air quality monitoring	Ambient air quality monitoring
Declare national priority areas	Declare provincial priority areas	None
Prepare national priority areas AQMP	Prepare provincial priority areas AQMP	None
Prepare an annual report regarding the implementation of the AQMP	Prepare an annual report regarding the implementation of the AQMP	Prepare an annual report regarding the implementation of the AQMP
Prescribe regulations for implementing and enforcing the priority area AQMP	Prescribe regulations for implementing and enforcing the priority area AQMP	None
List activities	List activities	None
None	Perform emission licensing-authority functions	Perform emission licensing-authority functions
Declare controlled emitters	Declare controlled emitters	None
Declare and set requirements for controlled fuels	Declare and set requirements for controlled fuels	None
Set requirements for pollution prevention plans	Establish a programme of public recognition of significant achievement in air pollution prevention	None
Prescribe measures for the control of dust, noise and odours	Prescribe measures for the control of dust, noise and odours	None

Investigate and regulate transboundary pollution	None	None
Investigate potential international agreement contraventions	None	None

2.2. Legislation for Local Government

The Local Government: Municipal Systems Act (Act No. 32, 2000), together with the Municipal Structures Act (Act No. 117, 1998), establishes local government as an autonomous sphere of government with specific powers and functions as defined by the Constitution. Section 155 of the Constitution provides for the establishment of Category A, B and C Municipalities which each has different levels of municipal executive and legislative authorities. According to Section 156(1) of the Constitution, a Municipality has the executive authority in respect of, and has the right to, administer the local government matters (listed in Part B of Schedule 4 and Part B of Schedule 5) that deal with air pollution. Section 156(2) makes provision for a Municipality to make and administer by-laws for the effective administration of any matters which it has the right to administer as long as it does not conflict with national or provincial legislation. The Municipal Systems Act as read with the Municipal Financial Management Act (Act No. 56, 2003) requires Municipalities to budget for and provide proper atmospheric environmental services. In terms of the National Health Act (Act No. 61, 2004), Municipalities are required to appoint a health officer who is required to investigate any state of affairs that may lead to a contravention of Section 24(a) of the Constitution. Section 24(a) states that each person has the right to an environment that is not harmful to their health or well-being.

The Promotion of Access to Information Act (Act No. 2, 2000), in conjunction with Section 32 of the Constitution, entitles everyone to the right of access to any information held by government and private individuals that is required for the exercise or protection of any rights. The relevance of the right to information is that government, industry and private individuals can be compelled, through court proceedings if required, to make information available regarding the state of the atmosphere and pollution. The Promotion of Administrative Justice Act (Act No. 3, 2000), which was introduced by the State to give effect to Section 33 of the Constitution, provides everyone with the right to administrative action that is lawful, reasonable and procedurally fair and the right to be given written reasons when rights have been adversely affected by administrative action.

2.3. Local Air Quality By-Laws

Section 156(2) of the Constitution of the Republic of South Africa makes provision for a Local Municipality to make and administer by-laws for the effective administration of the matters which it has the right to administer as long as such by-laws do not conflict with National or Provincial legislation.

The Chris Hani DM is currently in the process of publishing a Municipal Health Services by-law. This by-law covers air quality as well as various other forms of environmental pollution. Air quality matters that will be governed under the by-law include smoke emissions from dwellings and other premises, emissions caused by open burning and vehicular emissions (CHDM, 2018).

The Department of Environmental Affairs (DEA) has developed a generic air pollution control by-law for Municipalities (Governmant Notice No. 579, 2010) which deals with most of the air quality management challenges expected in South Africa. The aim of the generic air quality management by-law is to assist Municipalities in the development of their own air quality management by-law within their jurisdictions. Furthermore, use of the generic by-laws as a template will help ensure uniformity across the country when dealing with air quality management challenges. The Municipal Health Services by-law does not follow this template.

2.4. Ambient Air Quality Standards

Standards provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants of air that are known or likely to be hazardous to human health and well-being (WHO, 2000; WHO, 2005). Once the guidelines were adopted as standards, they become legally enforceable. Air quality standards prescribe various averaging periods, including an instantaneous peak, a 1-hour average, a 24-hour average, a 1-month average and an annual average.

The DEA, previously referred to as the Department of Environmental Affairs and Tourism (DEAT), issued NAAQS for several criteria pollutants, including, benzene (C_6H_6), carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}), ozone (O_3) and sulphur dioxide (SO_2) (Government Notice No. 1210, 2009). In 2012, particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) was promulgated as a criteria pollutant in 2012 (Government Notice No. 486, 2012) (Table 3).

Table 3: National Ambient Air Quality Standards for Criteria Pollutants (Government Notice No. 1210, 2009; Government Notice No. 486, 2012)

Pollutant	Averaging Period	Concentration (µg/m³)	Concentration (ppb)
SO_2	10-minute running average	500	191
	1-hr average	350	134
	24-hr average	125	48
	Annual average	50	19
NO_2	1-hr average	200	106
	Annual average	40	21
CO	1-hr average	30	26
	8-hourly running average	10	8.7
O_3	8-hourly running average	120	61
PM_{10}	24-hr average	75	-
	Annual average	40	-
$PM_{2.5}$	24-hr average	40	-
	Annual average	20	-
Pb	Annual average	0.5	-
C_6H_6	Annual average	5	1.6

The NEM:AQA does not make provision for the setting of legally binding local air quality standards by local authorities. However, it is accepted that local authorities may establish more stringent ambient air quality guidelines than the NAAQS.

2.5. Dustfall Standards

The Department of Environmental Affairs (DEA) gazetted National Dust Control Regulations (NDCR) on 1 November 2013 (Government Notice No. R827, 2013). These regulations provide the standard for acceptable dustfall rates for residential and non-residential areas based on the ASTM D1739, 1970 version of the standard. The maximum permissible dustfall rate over a 30-day averaging period in residential areas is 600 mg/m²/day, and in non-residential areas 1 200 mg/m²/day. For both residential and non-residential areas, it is permissible to exceed these values twice a year and / or in non-sequential months (Table 4).

Table 4: Acceptable dustfall rates (Government Notice No. R827, 2013)

Restriction Areas	Dust Fall Rate (D) (mg/m^2/day), 30-day average)	Permitted Frequency of Exceeding Dust Fall Rate
Residential Areas	D < 600	Two within a year, not sequential months.
Non-Residential Areas	600 < D < 1,200	Two within a year, not sequential months.

Measures to control dust, as detailed in the NDCR (Government Notice No. R827, 2013), state that *"6 (1) Any person who has exceeded the dustfall standard set out in regulation 3 must, within three months after submission of the dustfall monitoring report, develop and submit a dust management plan to the air quality officer for approval"*.

Additional requirements enforceable by the NDCR are detailed in the Regulations and it is the responsibility of the facility or dust generating activity to ensure that the conditions of the NDCR are complied with.

3. CRITERIA POLUTANTS AND ASSOCIATED HEALTH AND ENVIRONMENTAL IMPACTS

Deteriorating urban air quality has implications for human health, climate and visibility. An overview of the criteria pollutants and associated human health and environmental impacts is discussed in the subsections below.

3.1. Human Health Impacts

3.1.1. Particulate Matter

Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm). The fine particles contain the secondarily formed aerosols such as sulphates and nitrates, combustion particles and re-condensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dust from roads and industries.

In terms of health effects, particulate air pollution is associated with respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions. Inhalable PM also leads to increased mortality from cardiovascular and respiratory diseases and from lung cancer (World Health Organization 2013) Particle size is important for health because it controls where in the respiratory system a given particle deposits. Fine particles have been found to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles (Pope & Dockery, 2006). Larger particles are deposited into the extrathoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2005).

In the past, daily particulate concentrations were in the range 100 to 1000µg/m3 whereas in more recent times, daily concentrations are between 10 and 100µg/m3. Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (World Health Organization 2000).

(a) Short-term exposure

Studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 µg/m^3). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function (Scapellato & Lotti, 2007). (Scapellato and Lotti 2007). Health effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function. Susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable. For example, exposure to particulate matter affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function (World Health Organization 2011). There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur (World Health Organization 2013).

(b) Long-term exposure

Long-term exposure to low concentrations (~10 µg/m^3) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (World Health Organization 2005). Studies have indicated an association between lung function, chronic respiratory disease and airborne particles. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10µg/m^3 increase in annual average particulate concentrations (World Health Organization 2000). Based on studies conducted in the USA, Europe and Canada, mortality is estimated to increase by 0.2–0.6% per 10 µg/m^3 of PM_{10} (World Health Organization 2005); Samoli et al., 2008). $PM_{2.5}$ is a higher risk factor than the coarse part of PM_{10} (particles in the 2.5–10 µm range), especially as a consequence of long-term exposure. Long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 µg/m^3 of $PM_{2.5}$ (Beelen 2008; Krewski 2009; Pope, CA, Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D. 2002). Those most at risk include the elderly, individuals with pre-existing heart or lung disease, asthmatics and children.

3.1.2. Sulphur Dioxide

SO_2 originates from the combustion of sulphur-containing fuels and is a major air pollutant in many parts of the world. Health effects associated with exposure to SO_2 are also associated with the respiratory system. Being soluble, SO_2 is readily absorbed in the mucous membranes of the nose and upper respiratory tract (Witschi & Last, 2001).

(a) Short-term exposure

The effects of short-term exposure to SO_2 include reductions in ventilatory capacity, increases in specific airway resistance, and symptoms such as wheezing or shortness of breath (World Health Organization 2005). Most information on the acute effects of SO_2 is derived from short-term exposure in controlled chamber experiments. These experiments have demonstrated a wide range of sensitivity amongst individuals. Acute exposure of SO_2 concentrations can lead to severe bronchoconstriction in some individuals, while others remain completely unaffected. Response to SO_2 inhalation is rapid with the maximum effect experienced within a few minutes. Continued exposure does not increase the response. The effects are, however, increased by exercise that increases the amount and depth of inhalation, and breathing through the mouth. Effects of SO_2 exposure are short-lived with lung function returning to normal within a few minutes to hours (World Health Organization 2000, 2005). (WHO, 2005).

(b) Exposure over 24 hours

The effects of exposure to SO_2, averaged over a 24-hour period, are derived from epidemiological studies in which the effects of SO_2, particulates and other associated pollutants are assessed. Studies of the health impact of emissions from the inefficient burning of coal in domestic appliances have shown that when SO_2 concentrations exceed 250 $\mu g/m^3$ in the presence of particulate matter (as sulphates), an exacerbation of symptoms are observed in selected sensitive patients. More recent studies of health impacts in ambient air polluted by industrial and vehicular activities have demonstrated at low levels effects on mortality (total, cardiovascular and respiratory) and increases in hospital admissions. In these studies, no obvious SO_2 threshold level was identified (WHO, 2005).

(c) Long-term exposure

Long-term exposure to SO_2 has been found to be associated with an exacerbation of respiratory symptoms and a small reduction in lung function in children in some cases. In adults, respiratory symptoms such as wheezing and coughing are increased. The Hong Kong "intervention" study (Hedley 2002) indicated significant health benefits, both immediate and long-term, in reducing SO_2 from a daily average of 44 µg/m^3 to 21 µg/m^3.

3.1.3. Nitrogen Dioxide

Nitric oxide (NO) is a primary pollutant emitted from the combustion of stationary sources (heating, power generation) and from motor vehicles. Nitrogen dioxide (NO_2) is formed through the oxidation of nitric oxide. Oxidation of NO by O_3 occurs rapidly, even at low levels of reactants present in the atmosphere. As a result, this reaction is regarded as the most important route for nitrogen dioxide production in the atmosphere. Health effects of NO_2 gas are related to its ability to dissolve in the moisture on any moist tissue surfaces to form nitric acid which can burn the delicate tissues. As such, NO_2 is an irritant asphyxiant gas which can produce severe irritation in the air passages and lungs (The State of Queensland 2011).

Nitrogen dioxide is an important gas, not only because of its health effects, but because it (a) absorbs visible solar radiation and contributes to visibility impairment, (b) could have a potential role in global climate change if concentrations were to increase significantly, (c) is a chief regulator of the oxidizing capacity of the free troposphere by controlling the build-up and fate of radical species, including hydroxyl radicals and (d) plays a critical role in determining ozone concentrations.

(a) Short-term exposure

Experimental toxicology indicates that nitrogen dioxide is a toxic gas (in short-term concentrations exceeding 200µg/m^3) with significant health effects (World Health Organization, 2005). However, short-term concentrations of NO_2 greater than 1880µg/m^3 (i.e. concentrations which are higher than those normally found in ambient air) are required to bring about changes in the pulmonary function of healthy adults (World Health Organization 2000). At concentrations greater than 1,880 µg/m^3 (1,000 ppb), changes in the pulmonary function of an adult is observed. Normal healthy people exposed at rest or with light exercise for less than 2 hours to concentrations above 4,700 µg/m^3 (2,500 ppb), experience pronounced decreases in pulmonary function. Asthmatics are potentially the most sensitive subjects although various studies of the health effects on asthmatics have been inconclusive. The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30 – 110 minutes to 565 µg/m^3 (301 ppb) during intermittent exercise (World Health Organization 2005).

(b) Long-term exposure

Animal studies have shown that exposure to 1880µg/m^3 over a period of several weeks to months, causes effects in the lungs and other organs such as the spleen and liver. Structural changes include a change in cell type in the tracheo-bronchial and pulmonary regions to emphysema-like effects. NO_2 concentrations as low as 940µg/m^3, can also increase the lung's susceptibility to bacterial and viral infections (World Health Organization 2000). It is known that these toxic effects of NO_2 might occur in humans, but because of differences in species sensitivity, the effects that are actually caused by a specific inhaled concentration of NO_2 cannot be deduced with any level of confidence (World Health Organization 2005).

It is very difficult to differentiate the effects of nitrogen dioxide from those of other pollutants in outdoor epidemiological studies. This is because the complex gas-particle mixture of NO_2, organic and elemental carbon, inorganic acids, $PM_{2.5}$ and ultrafine particles all usually come from the same combustion sources (World Health Organization 2005).

Epidemiological studies have been undertaken on the indoor use of gas cooking appliances and health effects. Studies on adults and children under 2 years of age found no association between the use of gas cooking appliances and respiratory effects. Children aged 5 – 12 years have a 20% increased risk for respiratory symptoms and disease for each increase of 28 µg/m^3 (15 ppb) NO_2 concentration, where the weekly average concentrations are in the range of 15 – 128 µg/m^3 (8 – 68 ppb) (World Health Organization 2005).

Outdoor studies consistently indicate that children with long-term ambient NO_2 exposures exhibit increased respiratory symptoms that are of a longer duration. However, no evidence is provided for the association of long-term exposures with health effects in adults (World Health Organization 2005).

3.1.4. Ozone

Ozone in the atmosphere is a secondary pollutant formed through a complex series of photochemical reactions between NO_2 and VOCs in the presence of sunlight. Sources of these precursor pollutants include motor vehicles and industries. Atmospheric background concentrations are derived from both natural and anthropogenic sources. Natural concentrations of O_3 vary with altitude and seasonal variations (i.e. summer conditions favour O_3 formation due to increased insolation). Diurnal patterns of O_3 vary according to location, depending on the balance of factors affecting its formation, transport and destruction. From the minimal levels recorded in the early morning, concentrations increase as a result of photochemical processes and peak in the afternoon. During the night, O_3 is scavenged by nitric oxide. Seasonal variations in O_3 concentrations also occur and are caused by changes in meteorological conditions and insolation. Quarterly mean (arithmetic average of daily values for a calendar quarter) O_3 concentrations are typically highest in summer (WHO, 2005).

Ozone is a powerful oxidant and can react with a wide range of cellular components and biological materials. Health effects and the extent of the damage associated with O_3 exposure is dependent on O_3 concentrations, exposure duration, exposure pattern and ventilation (WHO, 2005).

(a) Short-term exposure

Short-term effects include respiratory symptoms, pulmonary function changes, increased airway responsiveness and inflammation. Field studies in vulnerable persons (children, adolescents, young adults, elderly and asthmatics) have indicated that pulmonary function decrements can occur as a result of short-term exposure to O_3 concentrations in the range 120 – 240 µg/m^3 (61 – 122 ppb) and higher. Ozone exposure has also been reported to be associated with increased hospital admissions for respiratory causes and exacerbation of asthma (WHO, 2005).

(b) Long-term exposure

There is limited information linking long-term O_3 exposure to chronic health effects, however, there are suggestions that cumulative O_3 exposures may be linked with increasing asthma severity and the possibility of increased risk of becoming asthmatic (Katsouyanni, 2003).

Evidence provided by studies of health effects related to chronic ambient O_3 exposure is consistent in indicating chronic effects on the lung. Some studies have shown that long-term exposure to concentrations of O_3 in the range 240 – 500 µg/m^3 (122 – 255 ppb) causes morphological changes in the region of the lung resulting in a reduction in lung function (Katsouyanni, 2003).

3.1.5. Carbon Monoxide

Carbon monoxide (CO) is one of the most common and widely distributed air pollutants. CO is a tasteless, odourless and colourless gas which has a low solubility in water. In the human body, after reaching the lungs it diffuses rapidly across the alveolar and capillary membranes and binds reversibly with the haem proteins. Approximately 80 - 90% of CO binds to haemoglobin to form carboxyhaemoglobin (COHb) which is a specific biomarker of exposure in blood. The affinity of haemoglobin for CO is 200 – 250 times that for oxygen. This causes a reduction in the oxygen-carrying capacity of the blood which leads to hypoxia as the body is starved of oxygen.

Anthropogenic emissions of CO originate from the incomplete combustion of carbonaceous materials. The largest proportion of these emissions is produced from exhausts of internal combustion engines, in particular petrol vehicles. Other sources include industrial processes, coal power plants and waste incinerators. Ambient CO concentrations in urban areas depend on the density of vehicles and are influenced by topography and weather conditions. In the streets, CO concentrations vary according to the distance from the traffic. In general, the concentration is highest at the leeward side of the 'street canyon' with a sharp decline in concentration from pavement to rooftop level (Schwela, 2000).

(a) Short and Long-term exposure

The adverse health effects of CO vary depending on the concentration and time of exposure. Clinical symptoms range from headaches, nausea and vomiting, muscular weakness, and shortness of breath at low concentrations (10 ppm) to loss of consciousness and death after prolonged exposure or after acute exposure to high CO concentrations (>500 ppm). Poisoning may cause both reversible, short-lasting neurological deficits and severe, often delayed, neurological damage. Neurobehavioural effects include impaired co-ordination, tracking, driving ability, vigilance and cognitive ability at COHb levels as low as 1.5 - 8.2% (WHO, 2005).

High risk patients with regards to CO exposure include persons with cardiovascular diseases (especially ischaemic heart disease), pregnant mothers and the fetus and new-born infants. Epidemiological and clinical studies indicate that CO from smoking and environmental or occupational exposures may contribute to cardiovascular mortality (WHO, 2005).

3.1.6. Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are organic chemicals that easily vaporise at room temperature and are colourless. VOCs are released from vehicle exhaust gases, either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels. Short-term exposure to VOCs can cause eye and respiratory tract irritation and damage, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reactions, nausea, and memory impairment, damage the bone marrow and even death. Long-term exposure to high levels of VOCs has been linked to an increase in occurrence of leukaemia. VOCs can also cause damage to the liver, kidneys and central nervous system.

(a) Benzene

Benzene in air exists predominantly in the vapour phase, with residence times varying between a few hours and a few days, depending on the environment, climate and the concentration of other pollutants. The only benzene reaction, which is important in the lower atmosphere, is the reaction with hydroxy radicals. The products of this reaction are phenols and aldehydes, which react quickly and are removed from air by rain.

Benzene is a natural component of crude oil, and petrol contains 1 – 5% by volume. Benzene is produced in large quantities from petroleum sources and is used in the chemical synthesis of ethyl benzene, phenol, cyclohexane and other substituted aromatic hydrocarbons. Benzene is emitted from industrial sources as well as from combustion sources such as motor engines, wood combustion and stationary fossil fuel combustion. The major source is exhaust emissions and evaporation losses from motor vehicles, and evaporation losses during the handling, distribution and storage of petrol.

Information on health effects from short-term exposure to benzene is fairly limited. The most significant adverse effects from prolonged exposure to benzene are haematotoxicity, genotoxicity and carcinogenicity. Chronic benzene exposure can result in bone marrow depression expressed as leukopenia, anaemia and/or thrombocytopenia, leading to pancytopenia and aplastic anaemia. Based on this evidence, C_6H_6 is recognized to be a human and animal carcinogen. An increased mortality from leukemia has been demonstrated in workers occupationally exposed (WHO, 2005).

(b) Toluene

Toluene is produced from the catalytic conversion of petroleum and aromatization of aliphatic hydrocarbons and as a by-product of the coke oven industry. The bulk of production is in the form of a benzene-toluene-xylene mixture that is used in the back blending of petrol to enhance octane ratings. Toluene is used as a solvent, carrier or thinner in the paint, rubber, printing, cosmetic, adhesives and resin industries, as a starting material for the synthesis of other chemicals and as a constituent of fuels (WHO, 2005).

Toluene is believed to be the most prevalent hydrocarbon in the atmosphere. Reactions with hydroxy radicals are the main mechanisms by which toluene is removed from the atmosphere. The lifetime of toluene can range from a few days in summer to a few months in winter (WHO, 2005).

The short-term and long-term effects of toluene on the Central Nervous System are of great concern. Toluene may also cause developmental decrements and congenital abnormalities in humans. The potential effects of toluene exposure on reproduction and hormonal imbalances in women are also of concern. Men occupationally exposed to toluene at 5 – 25 ppm have also been shown to exhibit hormonal imbalances. Limited information suggests an association between occupational toluene exposure and spontaneous abortions at an average concentration 88 ppm. Toluene has minimal effects on the liver and kidney, except in cases of toluene abuse. Studies have not indicated that toluene is carcinogenic (WHO, 2005).

3.2. Environmental Impacts

Trace gases and aerosols impact climate through their effect on the radiative balance of the earth. Trace gases such as greenhouse gases absorb and emit infrared radiation which raises the temperature of the earth's surface causing the enhanced greenhouse effect. Aerosol particles have a direct effect by scattering and absorbing solar radiation and an indirect effect by acting as cloud condensation nuclei. Atmospheric aerosol particles range from dust and smoke to mists, smogs and haze (IPCC, 2006). Smog and haze are common in regions where certain geographic features, such as mountains, and weather conditions, such as temperature inversions, contribute to the trapping of air pollutants (Kumar & Mohan, 2002). Smog and haze also contribute to visibility degradation through the absorption and scattering of radiation by gases and particulates (Elsom, 1996). This smog or 'brown haze' can be observed during the winter months (April to September) when strong temperature inversions and calm conditions promote the stagnation of pollutants.

Other environmental impacts associated with air pollution include loss of biodiversity, damage to sensitive environments and acid rain. Acid rain is a general term referring to a combination of wet and dry deposition from the atmosphere containing elevated amounts of sulphuric and nitric acid. Acid rain occurs when SO_2 and NO_x are emitted into the atmosphere, undergo chemical transformation and are absorbed by water droplets in clouds. The droplets then fall to earth as rain, snow, mist, dust, hail or sleet. This increases the acidity of soil and affects the chemical balance of dams and rivers. Acid rain can also cause damage to buildings and infrastructure.

4. METEOROLOGICAL OVERVIEW

An overview of the macroscale and mesoscale atmospheric circulations influencing airflow and the subsequent dispersion and dilution of pollutants is discussed. The local meteorological conditions in the Municipality are evaluated using surface meteorological data from air quality monitoring stations operated by the DEA.

4.1. Macroscale Air Circulations

The mean circulation of the atmosphere over southern Africa is anticyclonic throughout the year due to the dominance of three semi-permanent, subtropical high-pressure cells over the subcontinent. Seasonal changes in the intensity and position of the high-pressure cells, together with the influence of the easterlies in the north and westerlies in the south, controls the climate of southern Africa.

Synoptic circulations within the general circulation influence the everyday weather of southern Africa. Subtropical control of southern Africa is affected through the three semi-permanent anticyclones, tropical control occurs through tropical easterly waves while temperate control occurs through travelling perturbations in the westerlies.

Anticyclones centred over the subcontinent are associated with subsidence of air which produces clear, dry, stable conditions. The frequency of occurrence of anticyclones reaches a maximum over the interior plateau in June and July (79%) with a minimum during December (11%) (Tyson, Kruger, & Louw, 1988). Although the dominant effect of winter subsidence is such that the mean vertical motion is downward, weather occurs when uplift is produced by localized systems. Subsidence associated with anticyclones is conducive to the formation of absolutely stable layers in the troposphere that prevent the vertical transport of pollution. Over the interior plateau, three stable layers occur at 700 hPa, 500 hPa, and 300 hPa with another layer at 800 hPa between the plateau and the coast. On days when these stable layers occur, dense haze layers are evident (Tyson, Garstang, & Swap, 1996). Absolutely stable layers at the surface in the form of surface inversions develop due to cooling during the night. Surface inversions prevent the vertical distribution of pollutants in the atmosphere which can reduce visibility during the early morning. During the day, the stable boundary layer is eroded away by heating and a mixing layer develops which may erode away the surface inversion (Tyson, Kruger, & Louw, 1988). Pollutants trapped below the surface inversion are then able to rise and disperse.

Over southern Africa, semi-stationary easterly waves form in deep easterly currents in the vicinity of an easterly jet. The waves are barotropic (axes not displaced with height) and the perturbations take the form of open waves or closed lows which are evident near the surface. Surface convergence and upper air divergence to the east of the wave produces strong uplift, instability and the potential for precipitation. Ahead of and to the west surface divergence and upper air convergence occurs, ensuring clear, dry conditions. Easterly lows are deeper systems than easterly waves, with surface convergence through the 500 hPa level to the east and divergence to the west. Such phenomena are associated with copious rains if airflow has a northerly component. Tropical disturbances are mainly a summer phenomenon and peak during the summer months of December and February.

Westerly waves are baroclinic, Rossby waves and are tilted westward with height. Westerly waves are associated with surface convergence and upper-level divergence which produce gentle uplift of air. Subsidence and stable conditions occur ahead of the trough with cloud and precipitation to the rear of the trough. Other disturbances in the westerlies include cut-off lows, southerly meridional flow, ridging anticyclones, west-coast troughs and cold fronts. Cold fronts occur together with westerly waves, depressions or cut-off lows. Cold fronts occur most frequently in winter and bring cool weather due to airflow from the south and south-west. Ahead of the front, northerly airflow is associated with divergence and subsidence that brings stable, clear conditions. Behind the front, southerly airflow, associated with low-level convergence causes cool conditions and rain (Tyson & Preston-Whyte, 2000). With the passage of a cold front, wind direction changes from north-west to west and south-west.

4.2. Mesoscale Air Circulations

Air transport near the surface can either be induced by horizontal spatial discontinuities in temperature, pressure and density fields or by topographically induced local winds such as those on slopes and in valleys. Such mesoscale circulations have implications for the transport and recirculation of pollutants in an airshed.

On slopes, differential heating and cooling of the air produces local baroclinic fields (Figure 2). During the day, the absorption of radiation by the slopes warms the air near the surface, initiating low-level, up-slope anabatic flow with an upper-level return flow to complete the closed circulation. During the night, the mechanism and the circulation are reversed as surface cooling produces down-slope katabatic flow and its return flow. The formation of frost hollows and the accumulation of fog and pollutants are associated with down-slope flow (Atkinson, 1981).

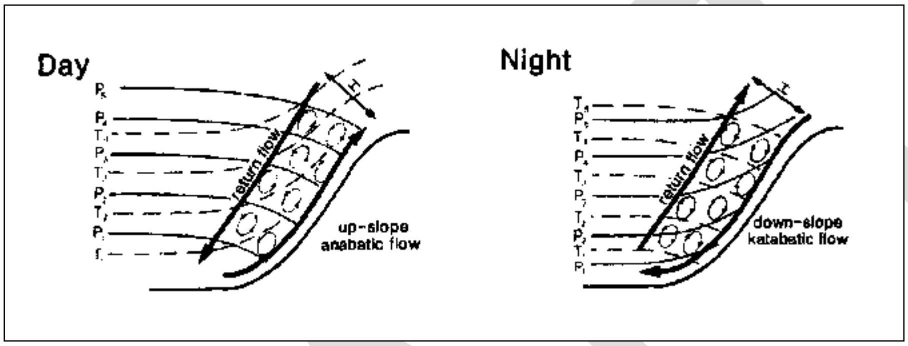

Figure 2: Diurnal variation of local winds on slopes (after Tyson and Preston-Whyte, 2000)

Within valleys, local airflow is dependent on the geometry (depth and orientation) of valleys and the time of day or night (Tyson & Preston-Whyte, 2000). In valleys whose slopes are equally heated (east-west valleys), early morning circulations are up-slope and down-slope in the evening (Figure 3).

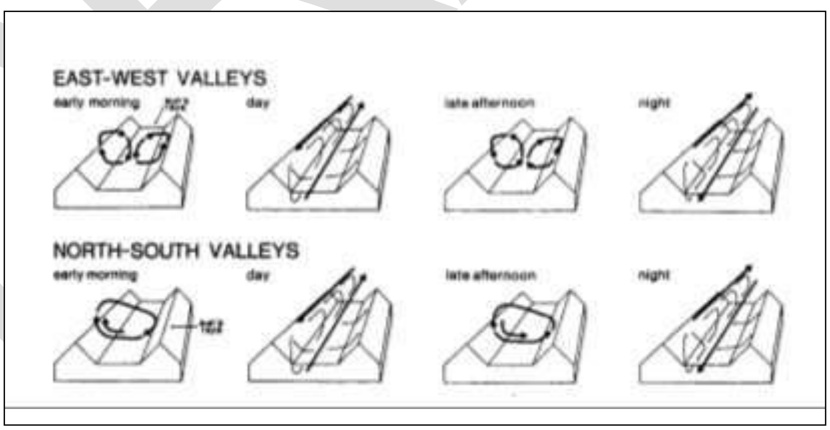

Figure 3: Diurnal variation of local winds in valleys (after Tyson and Preston-Whyte, 2000)

During the day, up-valley valley winds occur with an upper-level anti-valley wind to complete the closed circulation. During the night, down-valley mountain winds and the return anti-mountain wind occur. In valleys at right angles to the rising and setting sun (north-south valleys), the flow patterns are similar except that a unicellular circulation is set up at sunrise and sunset. These wind fields control the transport and dispersion of low-level pollutants within valleys (Tyson, Kruger, & Louw, 1988). Nocturnal mountain winds can transport pollution long distances down valleys under stable conditions while daytime valley winds can effectively disperse and dilute pollution trapped within the valley. Valley winds dominate and are strongest in summer when heating is greatest while mountain winds dominate and are strongest in winter when cooling is strongest (Tyson and Preston-Whyte, 2000).

4.3. Wind Field

Characterization of the wind field in Chris Hani DM was undertaken using surface meteorological data from available weather stations in the Chris Hani DM. Surface meteorological data was obtained from the South African Weather Service (SAWS) Monitoring Stations in Cradock, Elliot and Queenstown (Table 5) for the years 2015 to 2017.

Table 5: Meteorological stations operated by the DEA in the Chris Hani DM

Station Name/Town	Cradock	Elliot	Queenstown
Latitude (°S)	32°10'01"S	31°20'10"S	31°55'01"S
Longitude (°E)	25°37'30"E	27°50'24"E	26°52'41"E
Status	Active		
Monitoring Period	Unknown		
Parameters Measured	Wind speed, wind direction, temperature and rain		
Averaging Period	1-hour intervals		

Wind roses summarize the occurrence of winds at a location, representing their strength, direction and frequency. For the current period wind roses, each dotted circle represents a 6% frequency of occurrence during the monitoring period. Wind speed classes are represented as calm (< 0.5 m/s), light breeze (0.5 – 1.5 m/s; green), gentle breeze (1.5 – 2.5 m/s; dark blue), moderate breeze (2.5 – 3.5 m/s; blue), fresh breeze (3.5 – 4.5 m/s; light blue), strong breeze (4.5 – 5.5 m/s; yellow), near gale to strong gale (>= 5.5 m/s; orange). For this report, Summer has been defined as December to February, Autumn as March to May, Winter as June to August and Spring as September to November.

The predominant wind directions as measured at the monitoring station in Cradock are north-north-westerly, south-easterly and south-south-easterly (approximately 16% each)

(Figure 4). Similarly, the predominant wind directions as measured by the monitoring stations in Elliot and Queenstown are south-easterly (approximately 12%) and easterly (approximately 14%) respectively (Figure 5 and Figure 6).

Clear diurnal variation is present in the winds measured at Cradock Station. During the day, winds from the north-north-westerly direction dominate while at night, winds from the south-south-easterly direction dominate (Figure 4). Diurnal variation is present at both Elliot Station and Queenstown Station, even though it is less distinct that at Cradock Station (Figure 5 and Figure 6)

There is a seasonal shift in the dominant wind directions at all three weather stations. Cradock predominantly experiences winds between the north-westerly and northerly directions during Spring and Summer while during Autumn and Winter the dominant wind directions are between east-south-easterly and south-south-easterly (Figure 4). Winds between the east-south-easterly and south-south-easterly directions dominate at Elliot Station in Spring and Summer while those between the west-north-westerly and north-north-westerly directions dominate during Autumn and Winter. At Queenstown Station, easterly winds dominate in Spring, Summer and Autumn while winds from the westerly to north-westerly directions dominate in Winter.

Annually, Cradock experiences the highest average winds measured at the stations in Chris Hani DM (3.79 m/s) followed by Elliot (2.90 m/s) then Queenstown (2.40 m/s). Calms are experienced more at Cradock (40.71% of the time) than at Elliot (17.61% of the time) and Cradock (3.72% of the time). At all the weather stations, on average wind speeds are higher during the day than at night while calms are experienced more often at night. At Cradock Station, the highest average wind speed is experienced during Summer (4.40 m/s) and the lowest average wind speed during Winter (3.25 m/s). At Elliot and Queenstown Stations, the highest average windspeed is experienced during Spring (3.21 m/s and 2.42 m/s respectively) and the lowest during Autumn (2.42 m/s and 1.69 m/s respectively).

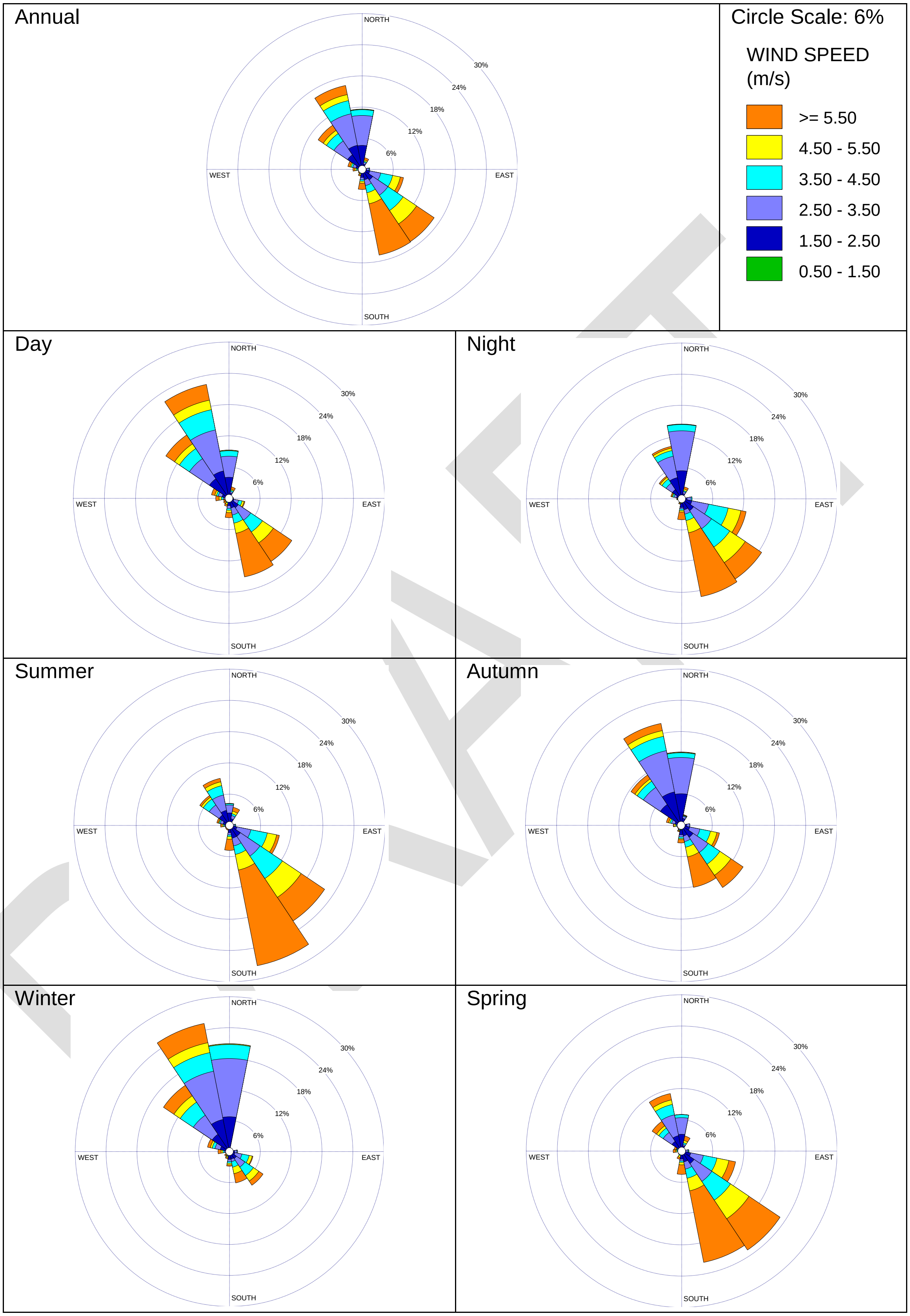

Figure 4: Wind roses of the average winds measured at the SAWS Station in Cradock

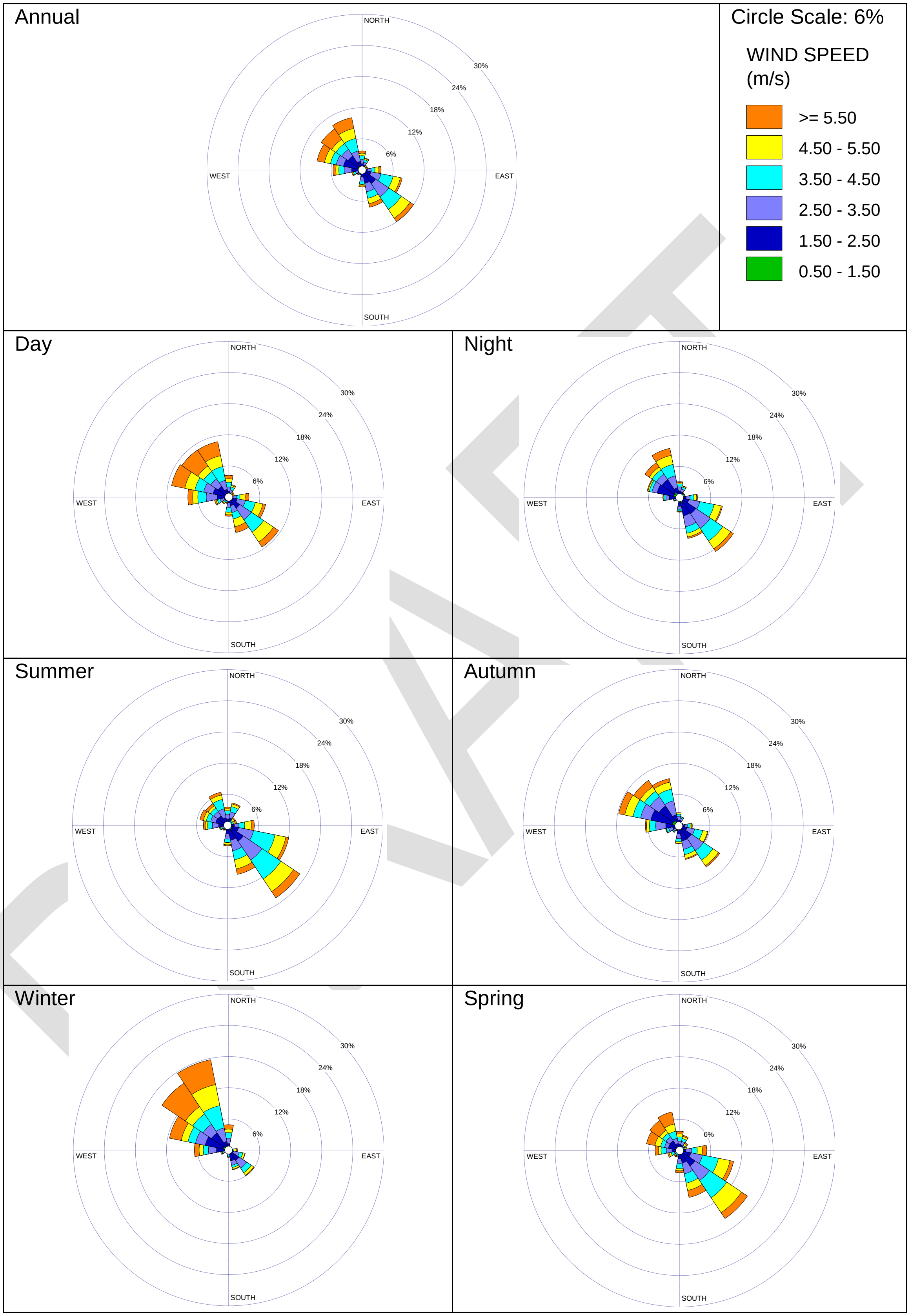

Figure 5: Wind roses of the average winds measured at the SAWS Station in Elliot

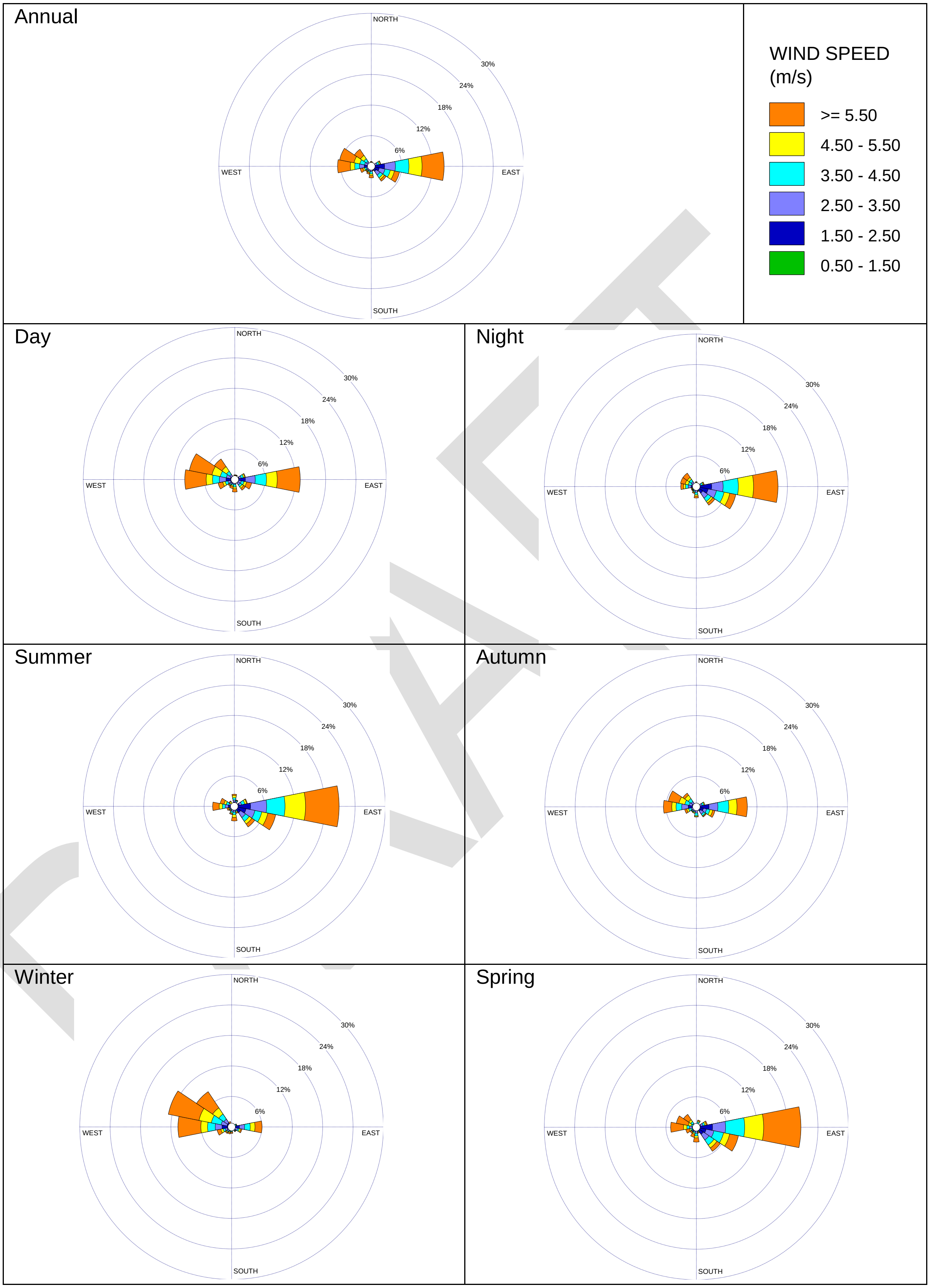

Figure 6: Wind roses of the average winds measured at the SAWS Station in Queenstown

4.4. Temperature

The seasonal averages for the temperature within Chris Hani DM were calculated using hourly data from the SAWS data collected during the years 2015-2017. These averages contain the daily minimum and maximum temperatures (Table 6).

Table 6: Chris Hani DM seasonal temperature averages

Monitoring Station	Seasonal Average (˚C)			
	Summer (Dec - Feb)	Autumn (Mar – May)	Winter (Jun – Aug)	Spring (Sept – Nov)
Cradock	22.3	17.3	11.4	17.3
Elliot	18.1	14.6	10.0	14.2
Queenstown	20.5	16.5	11.6	16.5

4.5. Precipitation

Daily precipitation amounts for Cradock, Elliot and Queenstown monitoring stations as well as seasonal averages were calculated using hourly data from SAWS for the years 2015 to 2017 (Figure 7, Figure 8, Figure 9 and Table 7). In Cradock, Elliot and Queenstown, Summer has the highest average daily rainfall and Winter has the lowest average daily rainfall (Table 7). Days with rainfall mainly occur in Summer followed by Autumn (Figure 10, Figure 11 and Figure 12).

Table 7: Chris Hani DM seasonal daily rainfall averages during the years 2015-2017

Monitoring Station	Seasonal Average (mm)			
	Summer (Dec - Feb)	Autumn (Mar – May)	Winter (Jun – Aug)	Spring (Sept – Nov)
Cradock	1.84	0.76	0.49	0.54
Elliot	3.34	1.56	0.61	1.61
Queenstown	2.40	1.48	0.66	0.92

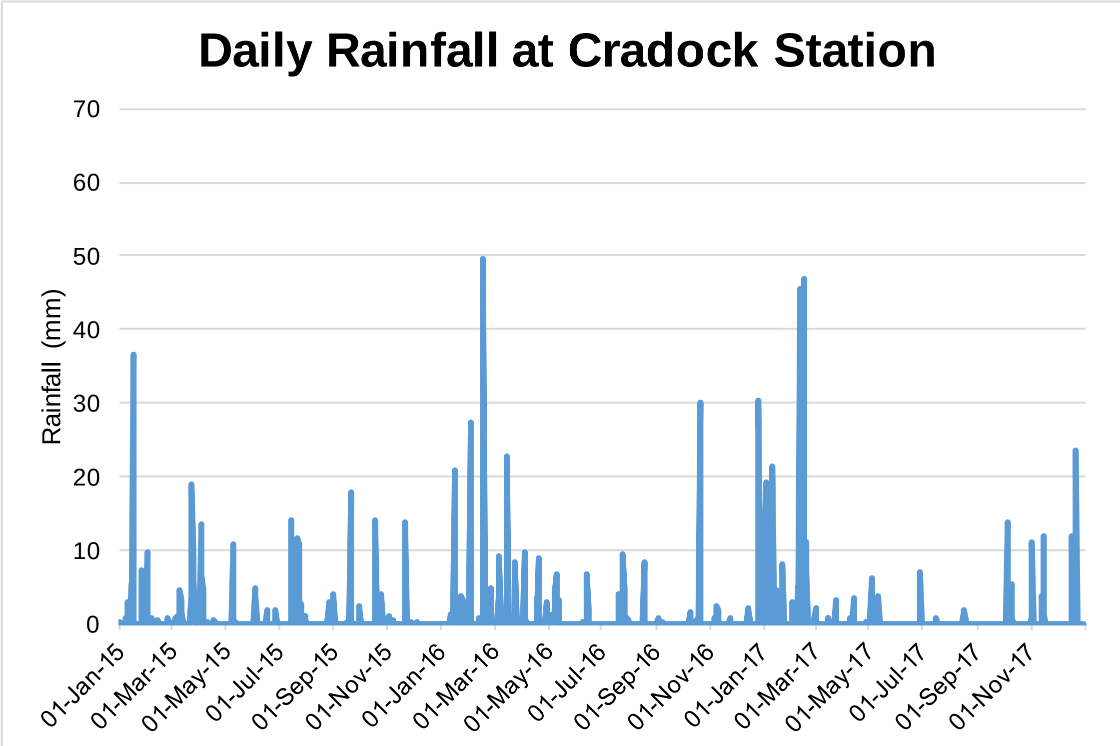

Figure 7: Daily rainfall at Cradock Weather Station during the years 2015-2017.

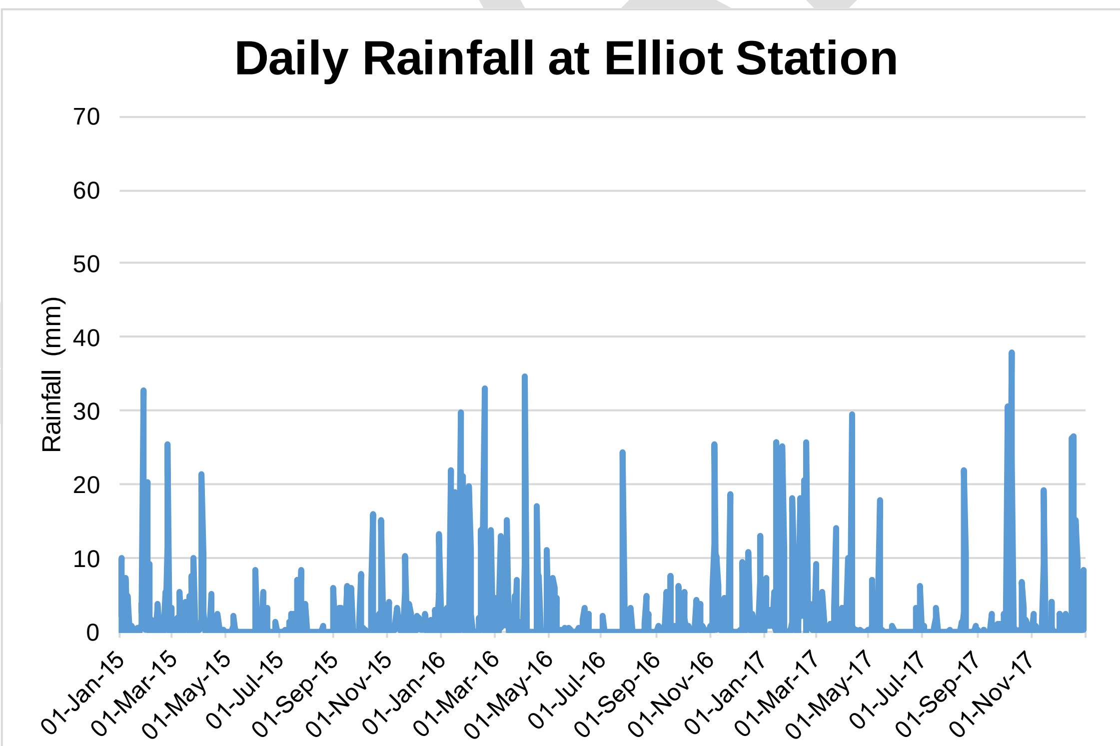

Figure 8: Daily rainfall at Elliot Weather Station during the years 2015-2017.

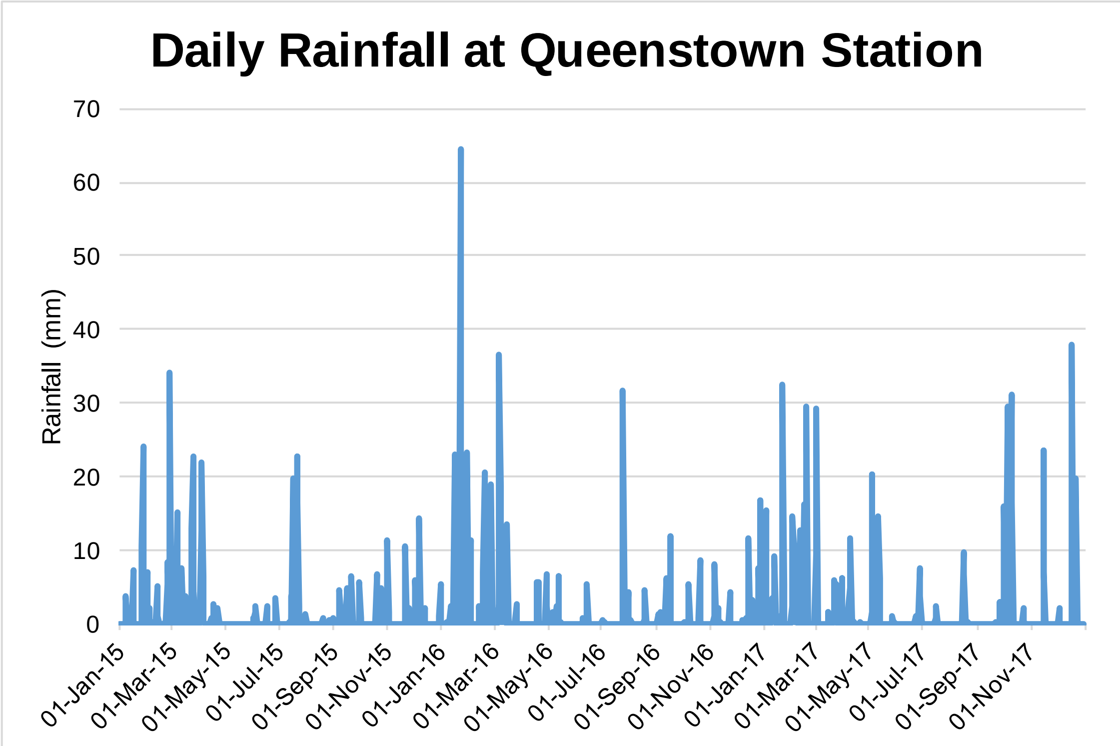

Figure 9: Daily rainfall at Queenstown Weather Station during the years 2015-2017.

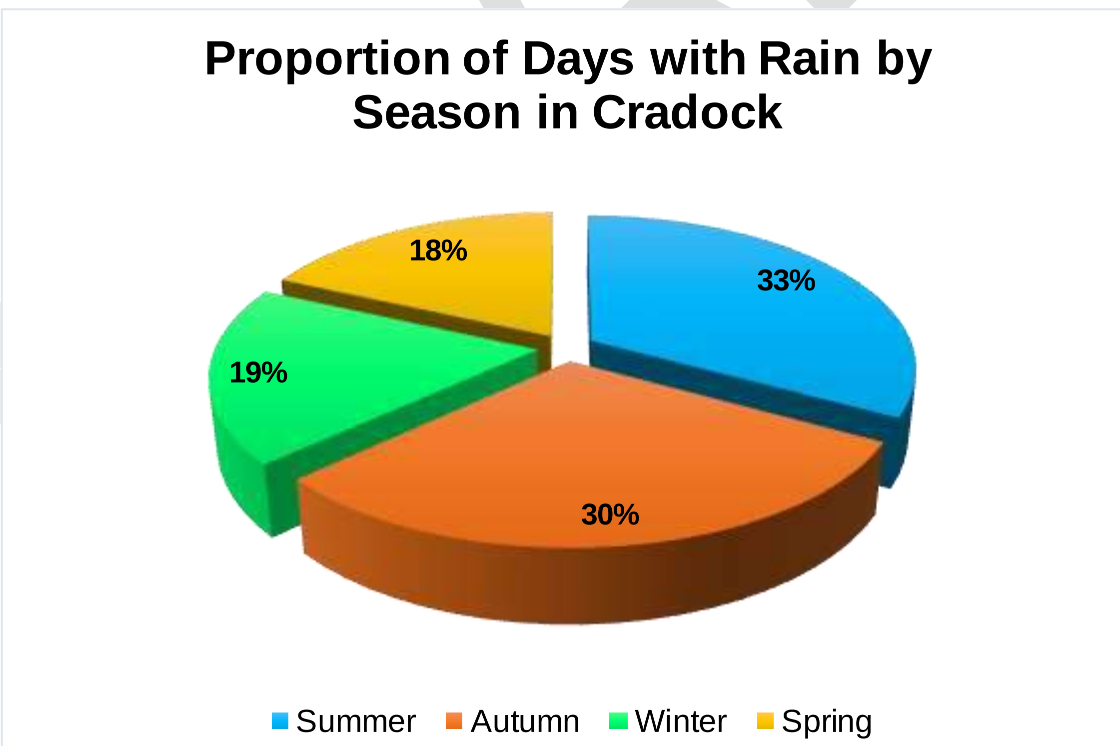

Figure 10: Proportion of rainfall by season at Cradock Monitoring Station.

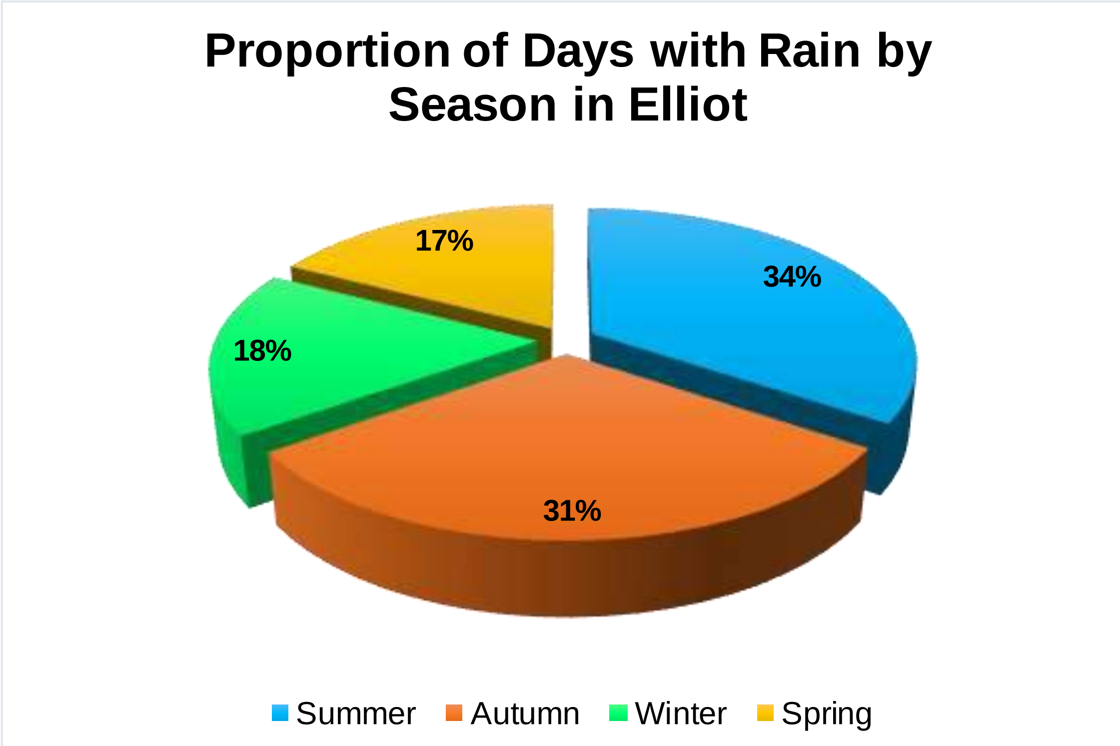

Figure 11: Proportion of rainfall by season at Elliot Monitoring Station.

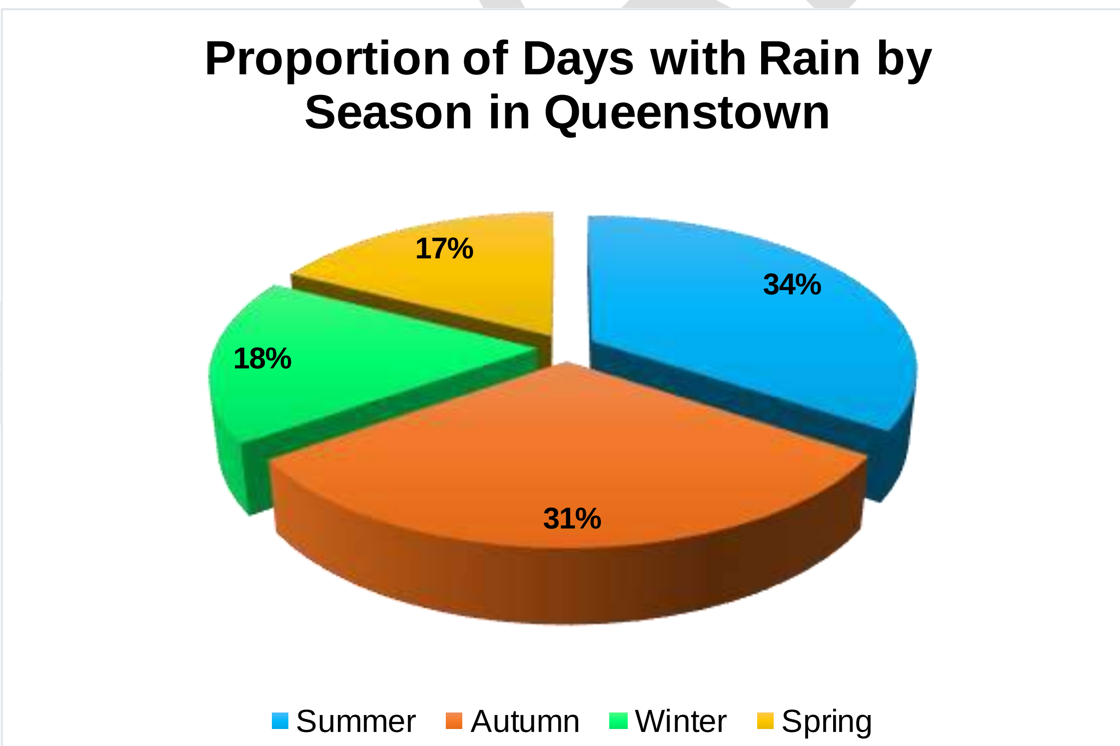

Figure 12: Proportion of rainfall by season at Queenstown Monitoring Station.

5. AMBIENT AIR QUALITY STATUS QUO

This section of the Chris Hani DM AQMP describes some background to emission sources and the baseline emissions inventory for the data that is available in the Chris Hani DM. An assessment of the current ambient air quality in the Chris Hani DM is undertaken through this emissions inventory.

5.1. Background to Emission Sources

This section contains background information about the different sectors identified in the Chris Hani DM that emit criteria pollutants. These sectors include: waste treatment and disposal, agricultural activities, biomass burning (veld fires), domestic fuel burning; denuded land, mining, landfills, vehicle tailpipe emissions and some industrial operations.

5.1.1. Listed Activities and Controlled Emitters

Large and small industries have the potential to emit pollutants, depending on their processes. South African legislation controls a large variety of industries through their classification as Listed Activities (Government Notice No. 893, 2013; Government Notice No. 551, 2015). In addition, where industries are not legislated as Listed Activities, they may be legislated under the Controlled Emitter regulations. Small boilers were declared controlled emitters in 2013 (Government Notice No. 831, 2013), temporary asphalt plants in 2014 (Government Notice No. 201, 2014) and small-scale char and small-scale charcoal plants in 2015 (Government Notice No. 602, 2015). Those industries that are not regulated under these laws are excluded from this study as their emission potential is considered negligible in comparison to the Listed Activities and Controlled Emitters. Data is not available for temporary asphalt plants, small-scale char plants or small-scale charcoal plants. As such, only the Listed Activities and Small Boiler industries are discussed hereafter.

(a) Listed Activities

Listed Activities were initially described in the Atmospheric Pollution Prevention Act (Act No. 45, 1965) as Scheduled Processes, based on the enterprises' process type. In 2004, Scheduled Processes were integrated into the NEM:AQA (Act No. 39, 2005) as Listed Activities that have or may have negative impacts on the environment, which includes health, social, economic, ecological and cultural environments. The Listed Activities are updated periodically, with the latest Listed Activities published in 2013 (Government

Notice No. 893, 2013) and the latest amendment published in 2015 (Government Notice No. 551, 2015).

(b) Small Boilers

Small boilers (boilers) are used not only by industries, but also by schools, hotels, restaurants, municipal offices, hospitals and a variety of commercial enterprises.

5.1.2. Vehicles

In developing countries, such as South Africa, improved road networks can increase welfare benefits as well as growth, however the detrimental effect on air quality and hence on human health should be taken into consideration (Berg, Deichmann, Liu, & Selod, 2016). Vehicles have the potential to contribute significant amounts of pollutants into the atmosphere, not only in localised areas, but throughout the surrounding airsheds. The health impact from transport emissions is often located away from the source of contamination due to the effect of dispersion, nonetheless, vehicle emissions are considered a significant source of urban pollution (Stone & Bennett, 2001).

Greenhouse gases (GHG) are among the highest pollutants emitted from vehicles. Developing countries are considered to be the fastest growing sources of GHG emissions due to the rapid expansion of road networks in these countries. The South African transport sector contributes 8.8% of South Africa's total GHG emissions with the road transport sector contributing 91.2% of these emissions (WWF, 2016). The increase in atmospheric pollution results in increased negative health impacts from the release of hydrocarbons, nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2) and particulate matter (PM) (Silva, Gonçalves, Farias, & Mendes-Lopes, 2006).

Vehicle emission concentrations vary according to the vehicle's size, age, engine, fuel specification and speed travelled, with the newer vehicles having significantly reduced emissions compared with vehicles manufactured in the 1980s (Burger, Stead, & Moldan, 2009). Vehicle emissions in South Africa have been identified as a growing concern, with increased emissions as a result of the increase in the number of vehicles, the age of the vehicles and the lack of emission control devices in a significant portion of South African vehicles (Burger, Stead, & Moldan, 2009). South Africa's vehicle fleet produces on average 21% more CO_2 emissions than the European fleet which indicates lower overall efficiency (Posada, 2017).

Increasing economic development has led to an increase in motorists on the road and an increased demand for fuel. The number of self-propelled vehicles has increased by 15% in South Africa and by 13% in the Eastern Cape Province between 28 February 2013 and 28 February 2018 (eNaTIS, 2013; eNaTIS, 2018). As the number of vehicles in the area increases, the amount of air pollution caused by vehicles is expected to increase. The large demand for vehicles in South Africa is due to the dispersed nature of land use in the country, requiring commuters to travel large distances between their residences and places of work.

The road network in the Chris Hani DM incorporates National and Regional roads (Figure 13). These enable the Municipality to act as a corridor between various locations in the Eastern Cape Province.

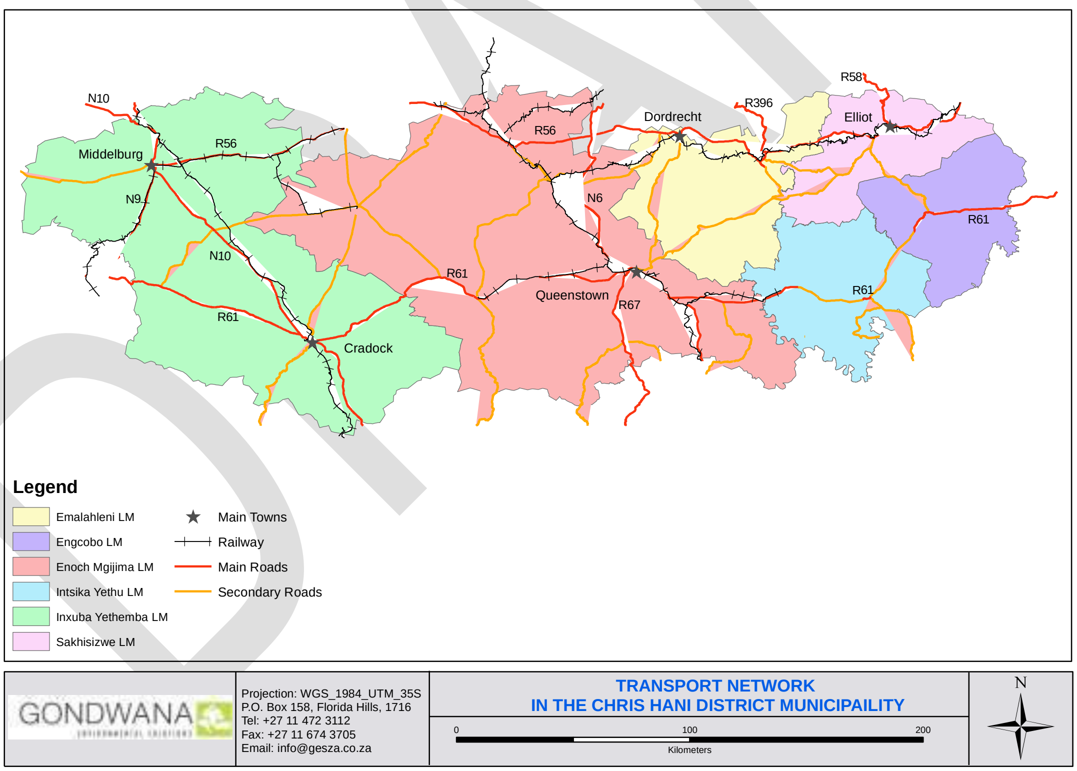

Figure 13: The Chris Hani DM transport network (NGI, 2008)

5.1.3. Domestic Fuel Burning

Domestic fuel usage is mostly found in densely populated, low-income and informal settlements. Fuels such as wood, paraffin and coal are widely used for cooking and heating, especially in the colder months. Domestic fuel burning is a source of atmospheric emissions and it contributes to PM, SO_2 and CO emissions. Human health impacts related to household coal and wood burning remains the most serious and pressing national air pollution problem (DEA, 2008; Vegter, 2016).

Coal burning emits a large amount of gaseous and particulate matter pollutants including SO_2, PM, heavy metals and inorganic ash, CO, benzo(a)pyrene and polycyclic aromatic hydrocarbons (PAH), which are recognised as carcinogens. Pollutants resulting from the combustion of wood include PM, NO_2, CO, PAH, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning within South Africa have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons (DEA, 2008).

Even though many people living in dense, low-income communities know and acknowledge that the burning of coal or wood may have a negative impact on their health and well-being, they continue to burn these fuels. The reason for this is simply that they cannot afford to use alternative energy sources to satisfy their needs (DEA, 2008).

5.1.4. Biomass Burning

The risk of veldfires in the various regions within Chris Hani DM ranges from low to extreme (Forsyth, Kruger, & Le Maitre, 2010). The vegetation types (Figure 14) combined with the climatic conditions, result in the potential for a high number of veld fires to occur in some regions and fewer in others (Figure 15). Each open fire, be it a veld fire or burning of garden refuse, adds CO, NO_x, SO_2, non-methane volatile organic compounds (NMVOCs), PM, ammonia (NH_3) and GHG to the atmosphere.

Air pollution in the Chris Hani DM is exacerbated in the winter months when the incidences of veld fires (together with the increased use of domestic fuel burning for heating) coincides with an inversion layer (warmer air trapped under a layer of colder air) that prevents the vertical dispersion of pollutants from escaping into the upper atmosphere.

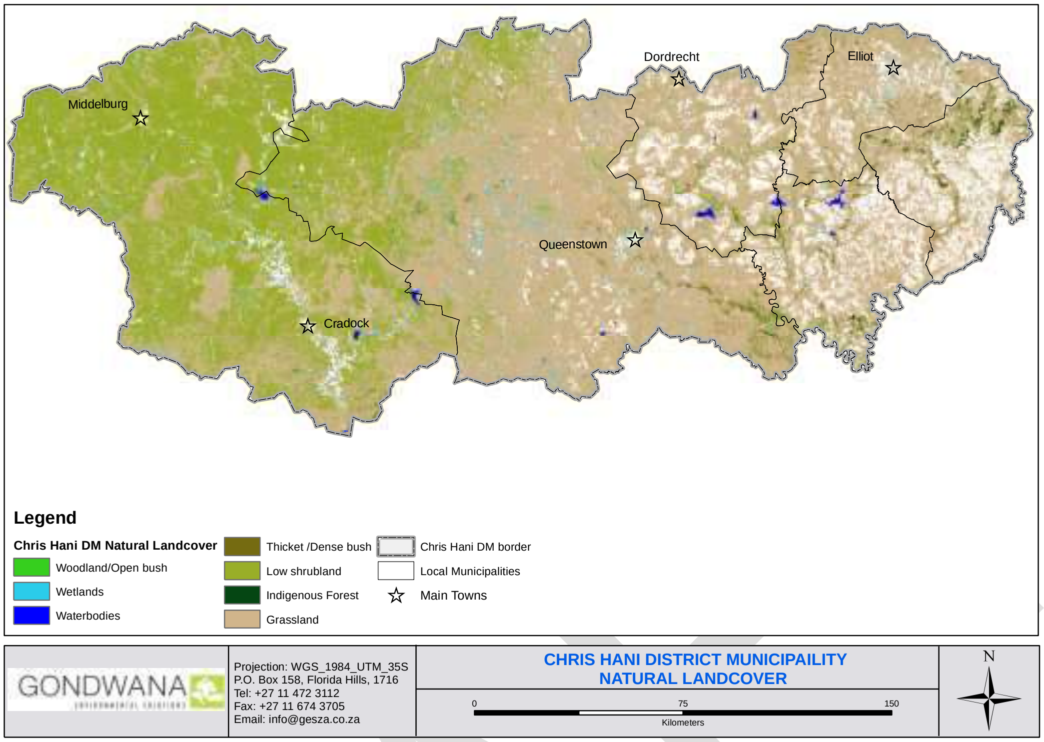

Figure 14: Distribution of natural land cover in the Chris Hani DM (DEA, 2015)

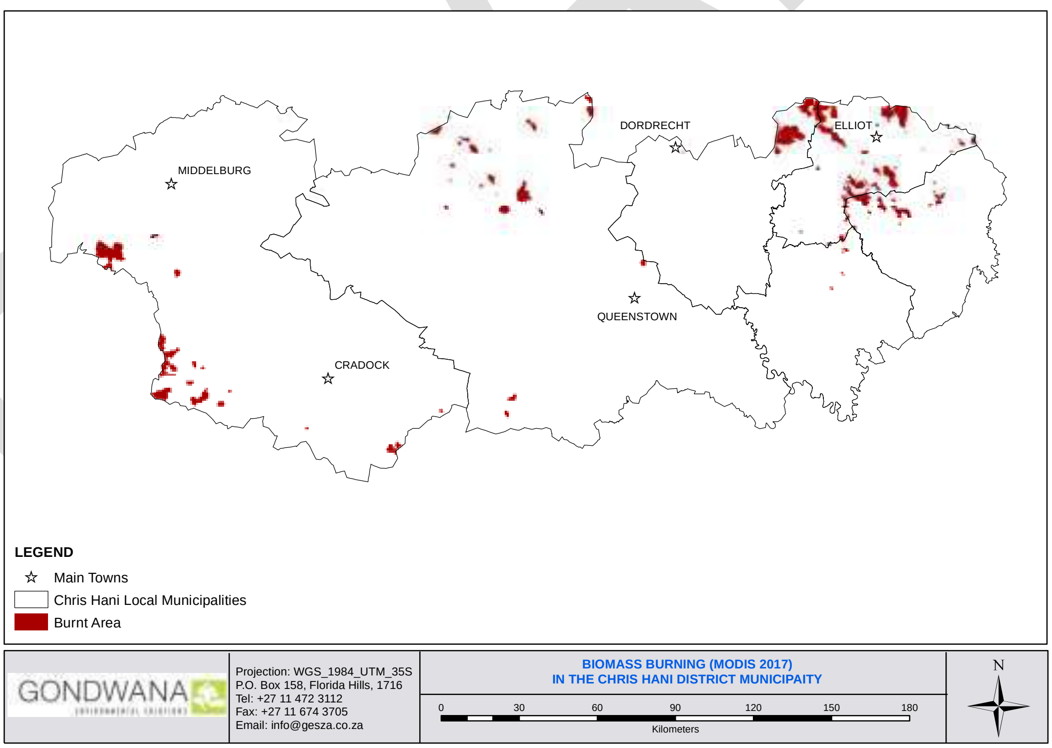

Figure 15: Distribution of burnt areas in the Chris Hani DM (Boschetti, Humber, Hoffmann, Roy, & Giglio, 2016)

5.1.5. Agricultural Activities

Agriculture is one of the main economic sectors within the Chris Hani DM and the Eastern Cape Province. Agricultural activities can be sub-divided into two groups – crop farming and livestock farming.

(a) Crop Farming

There are four main sources of emissions from crop farming and agricultural soils, with each source responsible for a particular emission (denoted in brackets):

- Fertiliser application (NH_3);
- Soil microbial processes (NO);
- Crop processes (NH_3 and NMVOCs); and
- Soil cultivation and crop harvesting (PM).

NH_3 emissions can cause acidification and eutrophication of natural ecosystems (EMEP/EEA, 2013). NH_3 may also form secondary PM. NO and NMVOCs play a role in the formation of O_3 which, near the surface of the Earth, can have an adverse effect on human health and plant growth. PM emissions also have an adverse impact on human health (EMEP/EEA, 2013).

Emissions of gaseous NH_3 and NO from crop farming and agricultural soils are generally closely related to the amount of nitrogen fertiliser applied. A fraction of N contained in the fertilizers is emitted into the atmosphere as NH_3 and NO. The emissions of NH_3 are influenced by the types and amounts of fertilizers, methods and timing of fertilizer application, types of soils to which fertilizers are applied, and climate factors. In the absence of detailed information related to these influencing factors, the emissions of NO can be calculated as a fraction of the total amount of N fertilizers applied (SCMEIEA, 2011).

Crop farming and agricultural soils are currently estimated to emit < 1% of total NMVOC emissions (EMEP/EEA, 2013); therefore, NMVOC emissions are not calculated in this study.

Windblown dust emissions from agricultural land can be influenced by non-climatic factors (Mansell, et al., 2003) as follows:

- Long-term effects of irrigation (i.e., soil "clodiness");
- Short-term effects of irrigation (i.e., surface soil wetness);
- Crop canopy cover;
- Post-harvest vegetative cover (i.e., residue);
- Post-harvest replanting (i.e., multi-cropping);
- Bare soil (i.e., barren areas within an agricultural field that do not develop crop canopy for various reasons); and
- Field borders (i.e., bare areas surrounding and adjacent to agricultural fields).

This level of information, however, is not available for agricultural activities in Chris Hani DM. Furthermore, PM emissions from soil cultivation and crop harvesting together account for > 80% of total PM_{10} emissions from tillage land.

The source strength of soil cultivation and crop harvesting depends on crop, soil type, cultivation method and weather conditions before and during working. Because of the absence of information on soil type and cultivation method, Tier 1 emission factors, based on crop type only, were used in this study.

Crop farming is distributed throughout the Chris Hani DM and covers a large proportion of the land in the Municipality (Figure 16). Potatoes are the most grown crop in the District, followed by lucerne and maize (Table 8).

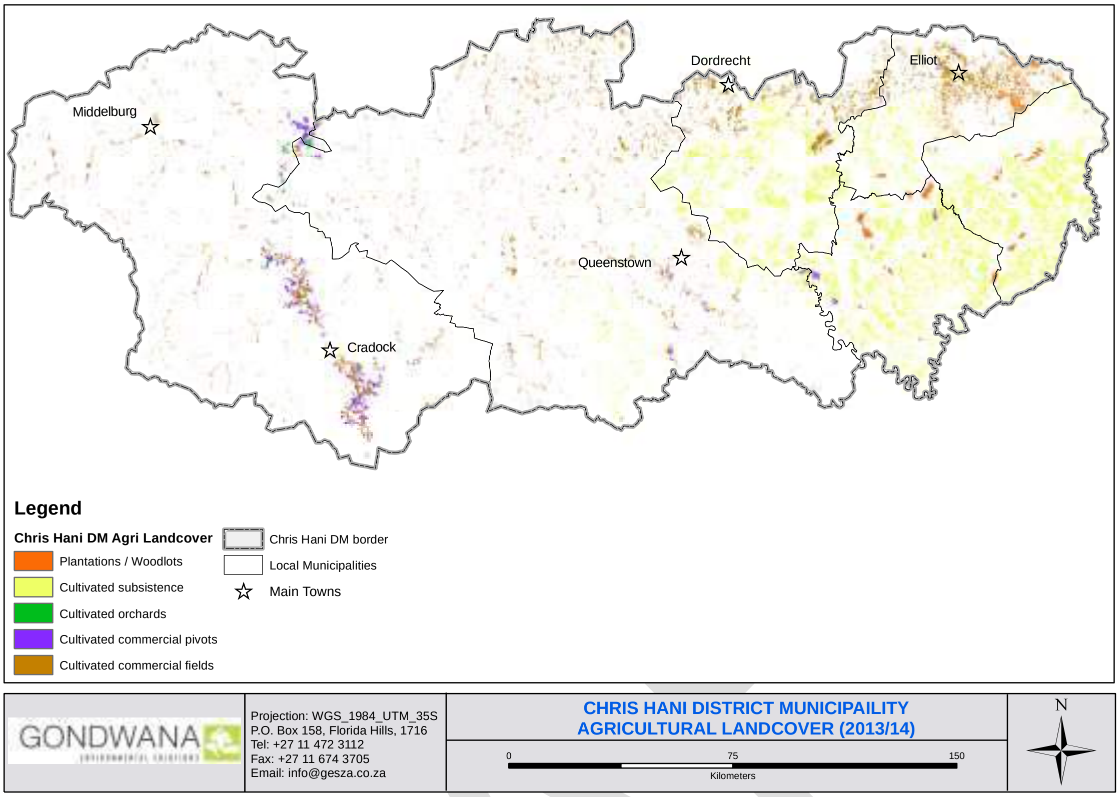

Figure 16: Distribution of agricultural activities in the Chris Hani DM (DEA, 2015).

Table 8: Area planted within Chris Hani DM

Municipality	Commercial Area	Area Planted (ha)					
		Maize	Wheat	Lucerne	Potatoes	Oranges	Nartjies
Emalahleni LM	Indwe	35	0	186	0	0	0
Enoch Mgijima LM	Hofmeyr	211	35	587	0	13	0
	Molteno	35	0	366	0	0	0
	Queenstown	2 009	0	871	2 758	0	0
	Sterkstroom	0	0	630	0	0	0
	Tarka	110	0	307	0	0	0
Intsika Yethu LM	Wodehouse	261	330	1 975	0	0	0
Inxuba Yethemba LM	Cradock	2 346	162	7 105	967	204	6
	Middelburg	964	275	971	423	0	0
Sakhisizwe LM	Elliot	4 343	182	345	12 127	0	0
Total		**10 314**	**984**	**13 343**	**16 275**	**217**	**6**

(b) Livestock Farming

There are four main sources of emissions from livestock farming with each source responsible for a particular emission (denoted in brackets):

- Livestock housing (PM);
- Livestock manure management (NH_3, methane (CH_4) and nitrous oxide (N_2O));
- Land spreading of manure (NO_x and NH_3); and
- Land spreading of urea (NH_3 and CO_2).

Information on manure and urea management is not available for the Chris Hani DM; therefore, only PM emissions have been calculated.

5.1.6. Denuded Land

A source of PM pollution is windblown dust from denuded land. For the purposes of this report, both the ‘erosion dongas’ and the ‘bare non-vegetated’ land-cover categories from the National Land-Cover Data Set (DEA, 2015) have been included in the area defined as denuded land. Based on this classification, denuded land comprises approximately 0.94% of the total area of the Chris Hani DM (Figure 17).

5.1.7. Mining

The Chris Hani DM mining sector is scarcely spread throughout the Municipality (Figure 18). The mining industry in Chris Hani DM consists mainly of sand and coal mines. PM is the main pollutant emitted by coal mines with sources of PM including the use of vehicles on unpaved and paved roads for transporting ore, personnel, waste rock, etc.; blasting; overburden stripping; ore and overburden handling; crushing and screening of ore; and wind entrainment from stockpiles (Government Notice No. 144, 2012). Similarly, PM is the main pollutant emitted by sand mines.

5.1.8. Landfills

The disposal of waste at landfill sites has a potentially negative impact on the environment in a number of ways, including emissions to the atmosphere. These emissions can cause a nuisance, odour and health impact. Significant health effects occur within 500 m of a well-managed landfill (DEA, 2007). The impact of odour can occur between 200 m and 5 km from the landfill depending on the management of the facility (DEA, 2007). While landfills emit GHGs, the primary criteria pollutants emitted are PM and C_6H_6. Landfills are found near towns or cities. Although there may be many informal landfills, only licensed landfills and those in the process of becoming licensed have been quantified in this project.

5.1.9. Wastewater Treatment Works

According to the Department of Water and Sanitation there are 16 wastewater collection and treatment systems in Chris Hani DM (DWA, 2013; DWS, 2014). Wastewater treatment works (WWTW) are located near urban areas and, therefore, are not distributed evenly throughout the Municipality.

5.1.10. Other Emission Sources

Sources of emissions to the atmosphere are widely varied and it is not possible to cover them all in this project. Some examples of sources that have not been quantified include:

- Aircraft;
- Illegal waste burning; and
- Emissions from unpaved roads by vehicle entrainment.

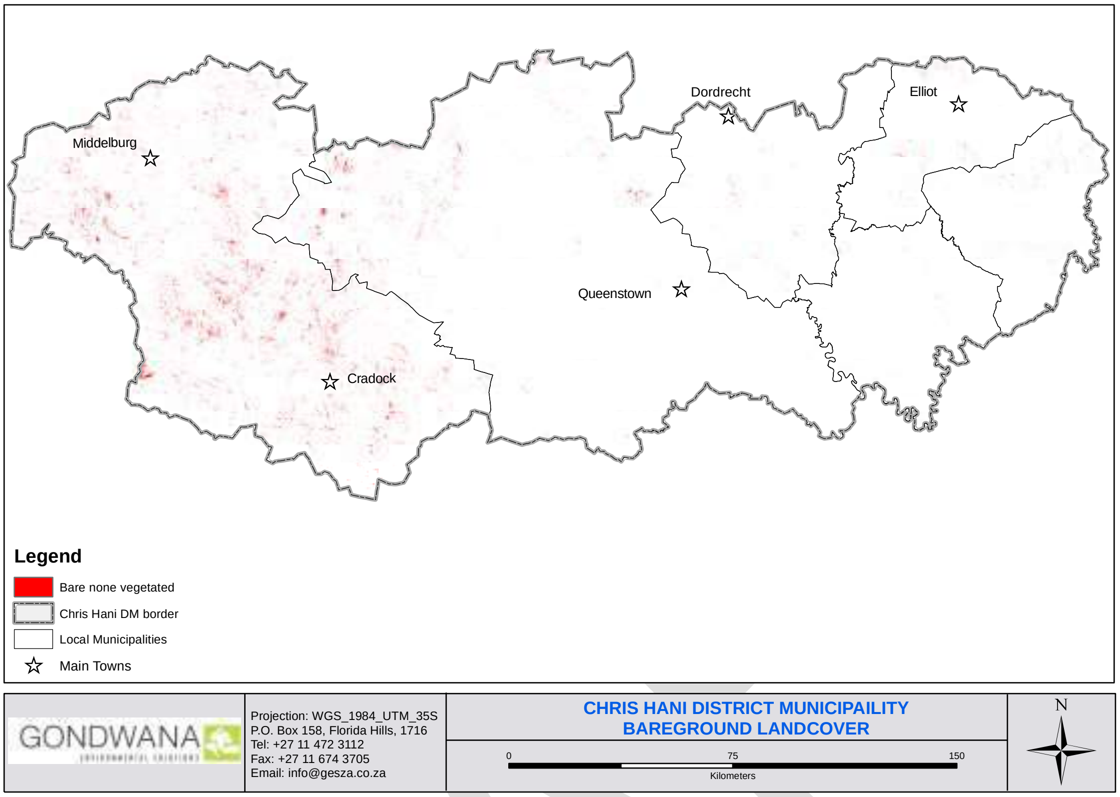

Figure 17: Distribution of denuded/degraded land in the Chris Hani DM (DEA, 2015)

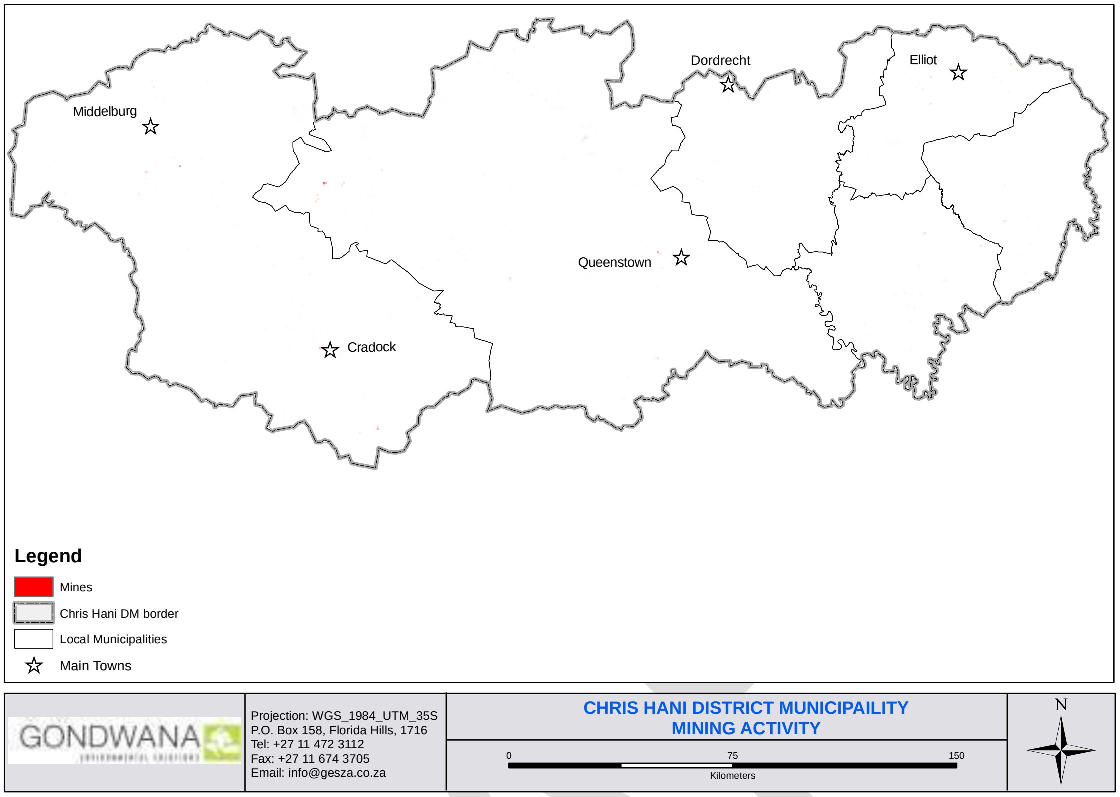

Figure 18: Distribution of mining activities in the Chris Hani DM (DEA, 2015)

5.2. Methods

Quantification of emissions by monitoring is almost non-existent in the Chris Hani DM. The overarching method to determine emissions from various sources is as follows:

Equation 1: Generalized Emissions Rate Calculation

$$Emission\ Rate = Emission\ Factor\ \times Activity\ Rate$$

Where:

- Emission Rates have units of (*Mass of Pollutant x Time*$^{-1}$);
- Emission Factors have units of (*Mass of Pollutant x Activity*$^{-1}$) where activity can be expressed in a variety of ways, e.g. mass of product, mass of raw material, area covered, volume of material processed, etc.; and
- Activity Rates have units of (*Activity x Time*$^{-1}$).

Emission Factors are obtained from the literature such as the United States Environmental Protection Agency, AP42 documents (US EPA, 1995) and the Australian National Pollutant Inventory (NPI) Emission Estimation Technique Manuals (NPI, 2011; NPI, 2012).

Activity rates are obtained from literature, information received directly from the sources themselves, or estimated by comparison to similar sources in the literature.

5.2.1. Listed Activities and Controlled Emitters

(a) Listed Activities

Information regarding two out of the four Listed Activities identified by Chris Hani DM was available from the National Atmospheric Emission Inventory System (NAEIS) (see Appendix 1). It is imperative that investigations into the remaining Listed Activities be conducted and emissions licenses be issued where appropriate. Information regarding the number of tons of fuel used, stack height, stack temperature, stack diameter, gas exit velocity, gas volumetric flow and mitigation methods as well as emissions per year are recorded in the NAEIS. This information provides the framework for an emissions inventory of Listed Activities.

(b) Small Boilers

Enterprises using boilers were identified primarily by means of Google Earth images and phone calls made to likely enterprises (see Appendix 2). An investigation should be undertaken by the District in order to identify any remaining small boilers. Specific fuel and boiler types were not available for all boilers within Chris Hani DM at the time of finalising this report. As such, various assumptions had to be made. Because stoker firing systems account for the vast majority of coal-fired water tube boilers for industrial, commercial, and institutional applications (US EPA, 1995), all coal-fired boilers were assumed to be overfeed stoker coal-fired boilers (an overfeed stoker uses a moving grate assembly in which coal is fed from a hopper onto a continuous grate which conveys the fuel into the furnace). Emissions for these were calculated on a per annum basis using emission factors (Table 9), Equation 2 and Equation 3. Because the majority of oil-fired boilers used in small commercial applications utilize distillate oils as fuel (US EPA, 1995), all oil-fired small boilers identified within Chris Hani DM were assumed to burn distillate oils and produce less than 100 million Btu/hr. Emissions for these were calculated on a per annum basis using emission factors (Table 10), Equation 4 and Equation 5.

Table 9: Emission factors for overfeed stoker coal-fired boilers (US EPA, 1995)

Emission Factor - Pollutant (lb/ton)				
SO_2	**NO_x**	**CO**	**PM_{10}**	**$PM_{2.5}$**
38	7.5	6	6	2.2

Equation 2: SO_2 emission calculation for coal-fired boilers

$$SO_2\left(\frac{kg}{year}\right) = Emission\ Factor\ \times Fuel\ Sulphur\ Content\ (\%) \times Fuel\ Usage\ \times 0.5$$

Where:

- The sulphur content for South African coal was taken as 2% (Kalenga, 2011).
- The factor 0.5 is the conversion factor from pounds per ton to kilograms per metric tonne.

Equation 3: NO_X, CO and PM_{10} emission calculations for coal-fired boilers

$$Pollutant\left(\frac{kg}{year}\right) = Emission\ Factor\ \times\ Fuel\ Usage\ \times 0.5$$

Table 10: Emission factors for distillate oil-fired boilers producing less than 100 million Btu/hr (US EPA, 1995)

Emission Factor - Pollutant (lb/1 000 gal distillate oil fired)				
SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$
142	20	5	1.08	0.83

Equation 4: SO_2 emission calculation for oil-fired boilers

$$SO_2\left(\frac{kg}{year}\right) = Emission\ Factor\ \times Fuel\ Sulphur\ Content\ (\%) \times Fuel\ Usage\ \times 0.12$$

Where:

- The sulphur content for distillate oil was taken as 0.3% (US EPA, 1995).
- The factor 0.12 is the conversion factor from pounds per 1 000 gallons to kilograms per kilolitre.

Equation 5: NO_X, CO and PM_{10} emission calculations for oil-fired boilers

$$Pollutant\left(\frac{kg}{year}\right) = Emission\ Factor\ \times\ Fuel\ Usage\ \times 0.12$$

5.2.2. Vehicles

Emissions resulting from traffic in the Chris Hani DM were quantified using total fuel sales statistics for towns within the District. This method is inherently biased to localised areas and interpolation for the entire region is simplistic; however, it does provide an indication of fuel-related emissions for the region. The main assumption of this emission calculation is that all fuel sold in the Chris Hani DM is combusted in the Chris Hani DM airshed.

Quarterly fuel sales statistics from 2016 were available for Cofimvaba (St Marks), Cradock, Elliot, Engcobo, Glen Grey/Cacadu/Lady Frere, Hewu (Whittle Sea), Indwe, Maxesibeni (Mount Ayliff), Middelburg and Queenstown. These were obtained from the Department of Energy (DoE) (DoE, 2018). Fuel sales statistics from the DoE were provided in litres for petrol and diesel. Hence, these statistics were converted from litres to tons based on the density of petrol and diesel, using the SI Metric conversion rates as published in 2007. The density of petrol was taken as 737.22 kg/m^3 at 15.56°C (60°F) while diesel was assumed to have a density of 950[1] kg/m^3 at 15°C (59°F) (SIMetric, 2007). The equation used was as follows:

Equation 6: Fuel Sales Conversion to tons/year

$$Total\ Fuel\ \left(\frac{tons}{year}\right) = \frac{Total\ Fuel\ \left(\frac{kl}{year}\right) \times Fuel\ Type\ Density}{1000}$$

Emission factors (Table 11) were applied to the total fuel (tons per year) to determine the total emissions per pollutant, for petrol and diesel during 2016 for the criteria pollutants only.

Whilst emission factors are provided for Lead Replacement Petrol (LRP) and Unleaded Petrol (ULP), the DoE statistics do not separate this information. As such, a conservative assumption was made to only use the ULP emission rates, as the majority of non-diesel vehicles on Chris Hani DM roads would be vehicles using ULP fuel.

Table 11: Fuel emission factors (Ntziachristos & Samaras, 2000; Wong, 1999)

Fuel Emission Factor (kg/ton)			
Pollutant	Fuel Type		
	LRP	ULP	Diesel
NO_X	1.99	2.15	11.68
CO	16.13	10.7	3.54
SO_2	0.05	0.04	1.54
Benzene	0.03	0.02	-
Lead	0.02	-	0.64

[1] The density of diesel ranges between 820 and 950 kg/m^3; the upper limit of 950 kg/m^3 was used to determine the worst-case scenario.

5.2.3. Domestic Fuel Burning

Domestic fuel usage for cooking, heating and lighting comprises a wide range of sources including animal dung, candles, coal, electricity, gas, paraffin, solar power and wood in the Chris Hani DM. The three dominant fuels which have quantifiable emissions were paraffin, wood and coal. All other fuels used, except electricity, are consumed in small quantities, thus making their impact relatively insignificant.

To quantify emissions from paraffin, wood and coal within Chris Hani DM, information regarding the total mass of each fuel burned per annum is required. As this information is not available, the number of households utilizing each source and the average fuel usage per household were used to calculate an approximate total fuel combusted value. The estimated total annual fuel usage for paraffin, wood and coal was then multiplied by an emission factor (Table 12) to establish total criteria pollutant emissions per fuel type per year (Equation 5).

Equation 7: Domestic Fuel Burning Emissions

$$Pollutant\ \left(\frac{kg}{year}\right) = No.Households \times Fuel\ per\ Household \times Pollutant\ Emission\ Factor$$

Population data per Local Municipality from the StatsSA Community Survey 2016 was used. The total number of households using domestic fuel burning in the Chris Hani DM was 92 487 in 2016 (StatsSA, 2016). The 2016 survey data provides the number of households that utilized each fuel type for cooking, heating and lighting. Households can use one type of fuel for more than one purpose. Hence, to avoid overestimation of emissions, it was assumed that the maximum number of households using a specific energy source for either cooking or heating was the actual number of households that used the energy source. The emissions from lighting were regarded as negligible. A limitation associated with these assumptions is a household that utilizes a fuel for a less common use only will not be counted.

Average household quantities of paraffin and wood used as domestic fuel were derived from a study conducted by Van Nierop (1995) and average household quantities of coal were derived from Scorgie *et al.* (2005). Both studies were conducted in the Vaal Triangle. Paraffin usage was calculated at 173.33 litres per annum per household and wood at 0.22

tons per annum per household (van Nierop, 1995). Coal usage was calculated at 1.19 tons per annum per household (Scorgie, Watson, & Fischer, 2005). These values were used as a best estimate for this study to calculate the total amount of fuel used for each fuel type in the Chris Hani DM due to lack of alternative, site specific data.

Table 12: Emission Factors from Domestic Fuel Burning (Thomas, 2008)

Fuel Type	Domestic Fuel Burning Emission Factors (g/kg)		
	SO_2	NO	PM_{10}
Paraffin	0.1	1.5	0.2
Wood	0.2	1.3	17.3
Coal	11.6	4	12

5.2.4. Biomass Burning

Open veld fires are typically dynamic fires, in which a moving fire front passes through a fuel bed. The emission factors of the various smoke constituents are determined by the composition of the fuel and by the physical and chemical processes during combustion (Andreae & Merlet, 2001). This makes it difficult to predict the type and extent of pollution emissions from veld fires. Furthermore, the timing, location and movement of the fire front are unpredictable. Since the information needed to take these factors into account is not available, the calculations of the emissions undertaken in this report are taken as a Tier 1 approximation.

Biomass burning emissions are influenced by the type of vegetation and the season in which the biomass burns. Hectares of land burned per month in the Chris Hani DM from 2013 to 2017 were calculated using MODIS images (Boschetti, Humber, Hoffmann, Roy, & Giglio, 2016). Emission factors for the burning of savannah and grasslands (Table 13) will be used for criteria pollutants only.

Table 13: Emission factors of the air pollutants and GHGs from field burning in savannah and grassland (Andreae & Merlet, 2001)

Air pollutant / GHG	Emission Factor (kg of pollutant / ton of dry weight)
CO	65
NO_x as NO	3.9
SO_2	0.35
$PM_{2.5}$	5.4

The general equation used to estimate emissions from veld fires is:

Equation 8: Biomass burning emissions

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

Where:

- L_{fire}: emissions from veldfires (for each pollutant, tons x year-1);
- A: area burnt (ha);
- M_B: mass of fuel available for combustion (tons x ha-1). This includes biomass, underground litter and dead wood;
- C_f: combustion factor (dimensionless); and
- G_{ef}: emission factor (g x kg-1 dry matter burnt).

For the mass of fuel combusted in mid and late dry season burns, the default biomass density for temperate grasslands of 450 g/m^2 dry weight (EMEP/EEA, 2013) was used. This value is more or less in keeping with 4.1 tons of dry matter per hectare given for mid or late dry season burns in savannah grasslands (IPCC, 2006). For early dry season burns, the value of 2.1 tons of dry matter per hectare, given for early dry season burns in all savannah grasslands, was used (IPCC, 2006).

Fires occurring from November to April were considered to be 'early dry season' burns, and fires occurring from May to October were considered to be 'mid and late dry season' burns. The combustion factor (C_f) gives the proportion of pre-fire fuel biomass consumed. The mean value of 0.74 (IPCC, 2006) will be used for all burns.

5.2.5. Agricultural Activities

Emissions emanating from agricultural activities are categorised into (a) crop farming and agricultural soil emissions and (b) emissions from livestock farming. Both categories are discussed separately hereafter.

(a) Crop Farming and Agricultural Soil Emissions

NO_X and NH_3 emissions from unfertilised crops, with the exception of legumes, are usually considered to be negligible and all fertilized crops are treated the same. The Tier 1 approach for NH_3 and NO emissions from crop farming and agricultural soils uses the general equation.

Equation 9: NH_3 and NO emissions from agricultural practices

$$E_{pollutant} = AR_{fertiliser\_applied} \times EF_{pollutant}$$

Where:

- $E_{pollutant}$: amount of pollutant emitted (kg x year^{-1});
- $AR_{fertiliser\_applied}$: amount of N applied (kg x year^{-1}); and
- $EF_{pollutant}$: Emission factor of pollutant (kg x kg^{-1}).

Fertilizer use was calculated using nitrogen fertilizer use rates per crop type (Table 14). Crops such as grain sorghum and other summer cereals, barley and other winter cereals, teff and other fodder crops and seeds were categorised as 'other pastures'. The emission factors used were derived from the EMEP/EEA (Table 15).

Table 14: Proportions of crops fertilized, and average rates of nitrogen fertilizer use in South Africa (FAO, 2005; FSSA, 2004)

Description	Percent fertilized (%)	N Fertilizer Use Rate (kg/ha of the fertilized area)
Wheat	100	30
Sunflower	85	15
Soybeans	40	7
Lucerne	90	15
Other Pastures	30	50
Subtropical fruits/nuts	100	180
Groundnuts		0
Citrus	100	80
Deciduous Fruit	100	110
Vegetables	100	170
Potatoes	100	170

Table 15: Pollutant Emission Factors from Fertilizer Application (EMEP/EEA, 2016)

Air pollutant	NO	NH_3	PM_{10}	$PM_{2.5}$
Units	kg/kg fertilizer-N applied		kg/ha	
Emission Factor	0,04	0,05	1,56	0,06

The Tier 1 approach for PM emissions from crop farming and agricultural soils uses the general equation:

Equation 10: PM Emissions from Agricultural Practices

$$E_{pollutant} = AR_{area} \times EF_{pollutant}$$

Where:

- $E_{pollutant}$: amount of pollutant emitted (kg x $year^{-1}$);
- AR_{area}: area covered by crop (ha); and
- $EF_{pollutant}$: EF of pollutant (kg x ha^{-1} x $year^{-1}$).

It was decided to use emission factors for Greece and Great Britain (Table 16) for the crops grown in Chris Hani DM as country specific emission rates are not available for South Africa. Where possible, emission rates for Greece were preferred over those for Great Britain as the annual rainfall in Greece is closer to that of South Africa. The challenge here was the availability of data. No current crop data was available for Chris Hani DM. Therefore, Agricultural Census data for commercial areas within Chris Hani DM was used (StatsSA, 2007).

It should be noted that PM_{10} emissions from soil cultivation and harvesting originate at the sites where the tractors and other machinery operate and are thought to consist of a mixture of organic fragments from the crop, soil, minerals and organic matter. Total dust emissions contain only small proportions of PM_{10} and $PM_{2.5}$ (EMEP/EEA, 2016). It is important to note that the PM emissions calculated here are therefore intended to reflect the amounts found immediately adjacent to the field operations. A substantial proportion of this emission will normally be deposited within a short distance of the location at which it is generated.

Table 16: Emission Factors for PM for Greece and Great Britain (IIASA, 2000)

Crop types	Greece				Great Britain	
	PM_{10} (kg/ha/year)			$PM_{2.5}$ (kg/ha/ year)	PM_{10} (kg/ha/ year)	$PM_{2.5}$ (kg/ha/ year)
	Land Preparation	Harvest	Total	Total	Total	Total
Barley	4.15	1.95	6.1	1.35	6.945	1.136
Fruit	-	-	-	-	0	0
Maize	5.25	1.88	7.13	1.58	-	-
Oil seeds	-	-	-	-	6.945	1.136
Other Cereals	4.15	1.23	5.38	1.19	6.945	1.136
Pastures	0	0	0	0	0	0

Potatoes	25.56	1.91	27.46	6.1	2.87	0.231
Pulses	-	-	-	-	6.945	1.136
Rye	4.15	1.23	5.38	1.19	-	-
Soya	8.63	1.88	10.51	2.33	-	-
Stone fruits	0.08	0.09	0.17	0.04	-	-
Sugar beets	25.56	1.88	27.44	6.09	2.82	0.22
Vegetables	-	-	-	-	2.82	0.22
Vineyards	1.68	0.19	1.87	0.42	-	-
Wheat	4.15	2.25	6.4	1.42	9.48	1.698

(b) Livestock Farming

Emissions from livestock are calculated as follows:

Equation 11: Emissions from livestock

$$E_{pollutant\_animal} = AAP_{animal} \times EF_{pollutant\_animal}$$

Where:

- $E_{pollutant\_animal}$: amount of pollutant emitted (kg year^{-1});
- AAP_{animal}: annual average population; and
- $EF_{pollutant\_animal}$: EF of pollutant (kg year^{-1}).

The Department of Agriculture, Forestry and Fisheries (DAFF) provided the number of commercial goats, sheep and cattle in the different commercial areas within Chris Hani DM (DAFF, 2018). The number of communal animals within the District was unavailable at the time of this report, therefore emissions calculated only represent a portion of total livestock emissions for the District. PM_{10} and $PM_{2.5}$ emission factors for cattle, sheep and goats (Table 17) were taken from the European Environmental Agency (EEA) emission factor database (EMEP/EEA, 2016).

Table 17: Livestock emission factors (EMEP/EEA, 2016)

Animal types	PM_{10} (kg/head)	$PM_{2.5}$ (kg/head)
Cattle	0.45	0.295
Sheep/Goats	0.06	0.02

5.2.6. Denuded Land

Windblown dust emissions from denuded land is fraught with complexities, from the definition of denuded land, to the quantification of the emission (Maricopa, 2011):

"there are many factors that control the production of windblown dust beyond wind speed velocities and disturbance levels that cannot be directly accounted for in this dust scheme (e.g., soil texture, soil moisture, topography, land use, etc.). Data for these factors can be limited, non-existent or unreliable. It is also unknown what degree of importance each of these factors have when they combine in the processes that contribute to the production of windblown dust."

The extent of denuded land was obtained from land-cover data obtained from the National Land-Cover Data Set (DEA, 2015). Denuded land was extracted from the base dataset, converted to shapefiles and the area (km^2) calculated. The categories of 'erosion dongas' and 'bare non-vegetated land' were included. The total area of denuded land, based on this classification, in the Chris Hani DM is approximately 346 km^2, which is approximately 0.94% of the total land area.

Given the lack of detailed information required to perform a complex modelling estimation of emissions from denuded land, the approach taken in this study was to estimate the PM_{10} and $PM_{2.5}$ emissions of denuded land using a worked example from the literature (Maricopa, 2011). The emission factor for denuded land was thus calculated as follows:

Equation 12: Denuded Land Emission Factor

$$EF_{Pollutant} = ER_{Pollutant}/A$$

Where:

- $EF_{Pollutant}$: The estimated emission factor for Denuded Land (ton x km^{-2} x $year^{-1}$);
- $ER_{Pollutant}$: Average emission rate Vacant Land for the 2008 Maricopa County study (ton x $year^{-1}$) (Maricopa, 2011); and
- A: The total area of vacant land identified in the Maricopa County study (km^2).

The estimated emission factors for denuded land are calculated to be:

EF_{PM10} = 0.360 ton/km^2/year; and
$EF_{PM2.5}$ = 0.054 ton/km^2/year.

These emissions factors were used to calculate the estimated emission rate for denuded land using the denuded land area obtained from the land cover data set.

5.2.7. Mining

According to the Chris Hani DM 2018-2019 Draft IDP, there are currently seven operational mining companies within the District. Of these, six are sand mining companies and the seventh is a coal mining company. As data is not available regarding the proportions of land used for each type of mine, it is assumed that the ratio of land usage is the same as that of the number of companies in the District. Hence, for the purposes of this report, it was assumed that 6/7ths of the total area of mine land, as extracted from the National Land-Cover Data Set (DEA, 2015), is categorized as sand mine land and 1/7th of the total area of mine land is categorized as coal mine land.

Huertas (Huertas, Camacho, & Huertas, 2012) found that open pit coal mines in northern Columbia are emitting 0.726 and 0.180 kg of TSP and PM_{10}, respectively, per Mg of coal produced. It was also found that these mines are using on average 1.148 m^2 of land per Mg of coal produced per year. From these, an emission factor of 0.157 $kg/m^2/year$ was derived for PM_{10} emissions from coal mines.

An emissions factor for sand mines related to area mined was not available at the time of this report. Therefore, it was assumed that the emissions from sand mines in Chris Hani DM are the same as those calculated for a proposed quarry in Cyferfontein. Emission factors derived from the Air Quality Impact Assessment for the Cyferfontein quarry are given in Table 18.

Table 18: Emission factors for sand mining (Van Basten & Van Nierop, 2018)

Pollutant	Emission Factor ($kg/m^2/year$)
PM_{10}	0.653
$PM_{2.5}$	0.161

5.2.8. Landfills

Emissions from landfills are a function of the type and volume of waste in the landfill, and the length of time the waste has been in the landfill. There are currently 12 landfills within

Chris Hani DM (SAWIC, 2008). Sufficient data, e.g. the size of the existing landfill, was not available. Therefore, the amount of criteria pollutants emitted by the Chis Hani DM landfills was assumed to be the same as the average model output of three proposed landfill sites in the West Coast District Municipality (Table 19).

Table 19: Emission rates for an average South African landfill (Burger, Bhailall, & Van Basten, 2012)

Pollutant	Metric tons/year
Benzene	0.660
PM_{10}	0.244

5.2.9. Wastewater Treatment Works

The WWTW in Chris Hani DM, their associated capacities and capacity utilization percentages are described in the Green Drop reports published by the Department of Water and Sanitation (previously known as the Department of Water Affairs). Limited compliance monitoring was performed during the 2014 Green Drop reporting period (DWS, 2014), hence many values were not reported. Therefore, data from the 2013 report was used (DWA, 2013).

Emissions from WWTW depend on the type of wastewater entering the facility. However, this information is not available for the WWTW in Chris Hani DM. Therefore, the characteristic emission factor for VOCs (Table 20) from WWTW that has been determined by the Australian NPI (2011) was used in the WWTW emission calculations in this report.

Table 20: Emission Factor for Wastewater Treatment Works (NPI, 2011)

	Emission Factor (g/m^3)
VOCs	1.07

5.3. Emission Inventory Results

Results of emission calculations for the different sources are presented in this section.

5.3.1. Listed Activities and Controlled Emitters

(a) Listed Activities

Emissions from Listed Activities in Chris Hani DM were quantified using data from NAEIS (see Appendix 1). The total emissions from these Listed Activities are presented in Table

21. It should be noted that the total emissions from all Listed Activities in the Municipality may be significantly higher than those estimated here as some may not have been included in NAEIS at the time of this report.

Table 21: Emissions from listed activities in Chris Hani DM

Municipality	Source Name	Emissions (kg/year)				
		PM_{10}	$PM_{2.5}$	NO_x	CO	VOCs
Enoch Mgijima LM	AP Green Sawmills	1 936.2	1 429.0	2 460.7	1 336.9	-
Enoch Mgijima LM	East Cape Fuel	-	-	-	-	87.7
Total		**1 936.2**	**1 429.0**	**2 460.7**	**1 336.9**	**87.7**

(b) Small Boilers

Boilers were identified as potential stakeholders in this study that were not part of any listed activity. Two coal-fired boilers and two oil-fired boilers were identified in Chris Hani DM (see Appendix 2). The total emissions from boilers in Chris Hani DM for SO_2, NO_x, CO, PM_{10} and $PM_{2.5}$ are presented in Table 22.

Table 22: Total Emissions from Boilers in Chris Hani DM

	Total Number of Boilers	Fuel Type	Boiler Emissions (metric tons/year)				
			SO_2	NO_x	CO	PM_{10}	$PM_{2.5}$
Cofimvaba Hospital	1	Oil	525.81	246.86	61.71	13.33	10.24
Cradock Hospital	1	Oil	766.80	360.00	90.00	19.44	14.94
Frontier Hospital	2	Coal	5 320.00	525.00	420.00	420.00	154.00
Total	**4**	**-**	**6 612.61**	**1 131.86**	**571.71**	**452.77**	**179.18**

5.3.2. Vehicles

Fuel sales and emissions from fuel were calculated for towns within Chris Hani DM and subsequently the total emissions from fuel for the District. A total of approximately 72 thousand metric tonnes of diesel and 45 thousand metric tonnes of petrol was sold in Chris Hani DM in 2016 (Table 23). The most fuel was sold within Inxuba Yethemba LM (35%) followed by Enoch Mgijima (34%) (Figure 19). Benzene emissions are the largest of the criteria pollutant emissions from vehicles in Chris Hani DM by mass (Table 23).

Table 23: Annual Emissions from Vehicles within Chris Hani DM (DoE, 2018)

Local Municipality	Fuel Usage (metric tons/year)	Fuel Usage (metric tonnes/year)	Emissions from Vehicles (kg/year)

		Diesel	Petrol	Benzene	Lead	SO_2	CO	NO_x
Emalahleni	Glen Grey/ Cacadu/ Lady Frere	1 737	1 671	23 875	24 024	2 741	33	1 111
	Indwe	1 181	659	15 210	11 235	1 845	13	756
Engcobo	Engcobo	6 641	6 653	91 876	94 702	10 494	133	4 250
	Maxesibeni (Mount Ayliff)	2 620	3 374	37 852	45 379	4 169	67	1 677
Enoch Mgijima	Hewu (Whittle Sea)	658	1 474	10 853	18 103	1 072	29	421
	Queenstown	23 667	14 314	307 204	236 944	37 019	286	15 147
Intsika Yethu	Cofimvaba (St Marks)	13	-	155	47	20	-	9
Inxuba Yethemba	Cradock	7 236	3 754	92 586	65 782	11 293	75	4 631
	Middelburg (Eastern Cape)	18 970	10 772	244 730	182 417	29 645	215	12 141
Sakhisizwe	Elliot	9 306	2 488	114 041	59 561	14 431	50	5 956
Chris Hani DM		72 028	45 160	938 381	738 195	112 729	903	46 098

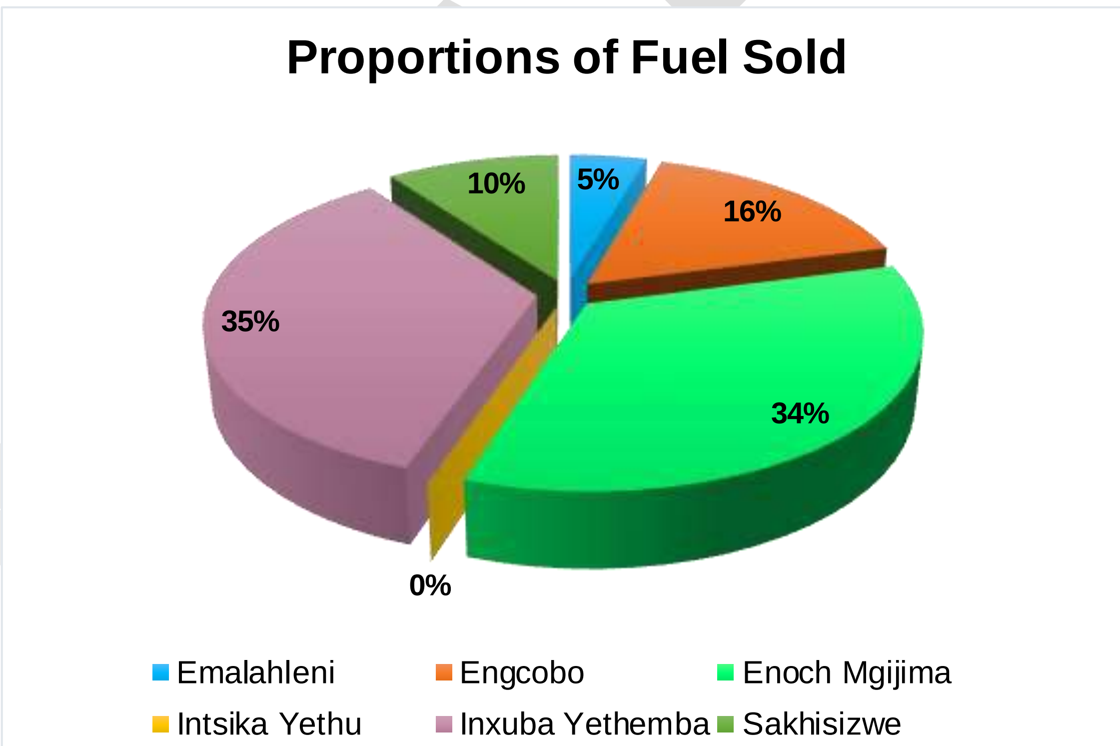

Figure 19: Fuel Usage in the Chris Hani DM

5.3.3. Domestic Fuel Burning

On average, 84.5% of households in the Chris Hani DM use electricity for cooking, 42.5% use electricity for heating and 91.4% use electricity for lighting (Table 24). Electricity is the most used domestic energy source for cooking, heating and lighting in all Local

Municipalities within the Chris Hani DM except for Intsika Yethu LM. In Intsika Yethu, wood is the most used domestic energy source used for heating while electricity is still the preferred energy source for cooking and lighting. After electricity, wood is the preferred energy source used for cooking in households in the Chris Hani DM and paraffin is the preferred energy source used for heating and lighting in the Chris Hani DM (Figure 20, Figure 21, Figure 22). Animal dung is the least used fuel for domestic burning in the Chris Hani DM.

Table 24: Households in the Chris Hani District Municipality using electricity (StatsSA, 2016)

Settlement	Number of Households	% of Households Using Electricity for Cooking	% of Households Using Electricity for Heating	% of Households Using Electricity for Lighting
Emalahleni LM	26 715	88.0	44.6	95.1
Engcobo LM	33 156	67.0	37.5	80.4
Enoch Mgijima LM	64 192	90.9	45.5	93.9
Intsika Yethu LM	33 869	80.9	29.4	91.8
Inxuba Yethemba LM	18 282	92.3	58.6	96.0
Sakhisizwe LM	15 142	87.5	46.5	92.1
Chris Hani DM	191 356	84.5	42.5	91.4

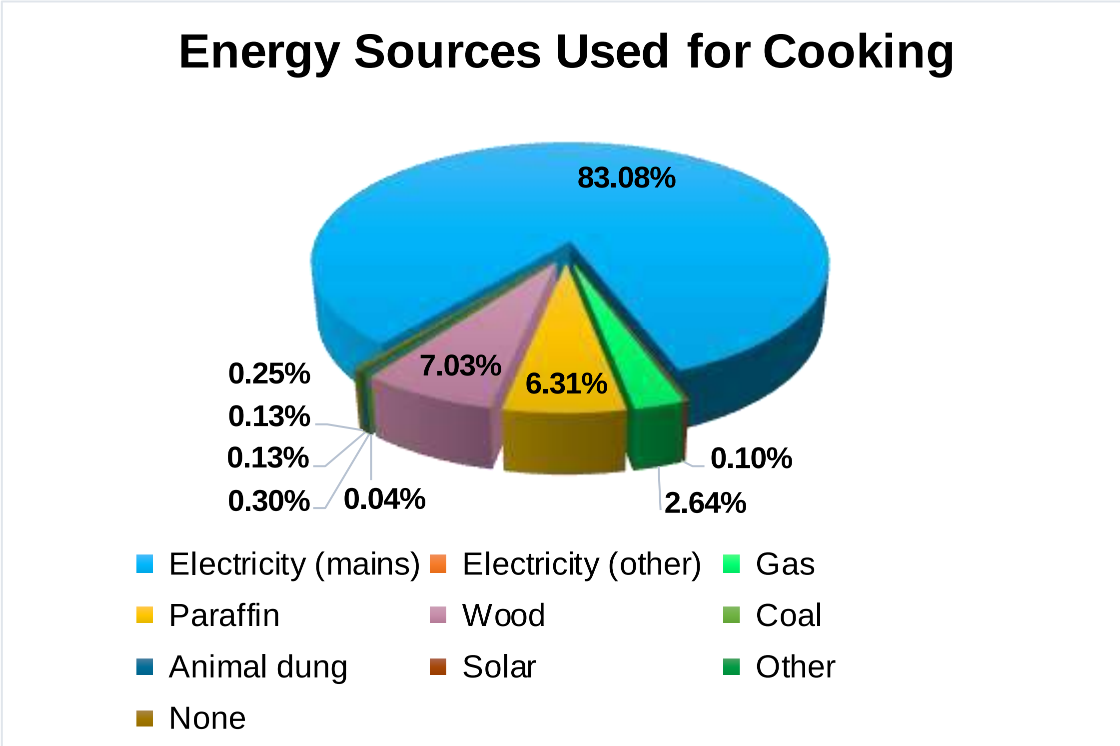

Figure 20: Energy Sources Used for Cooking in the Chris Hani DM

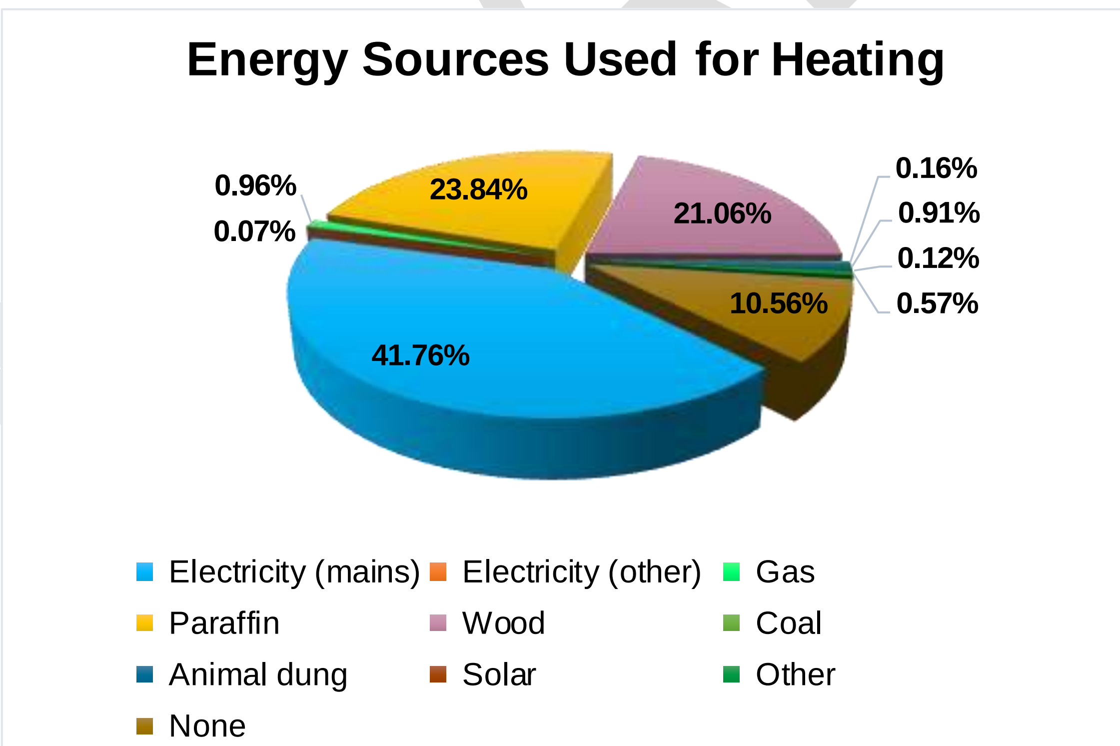

Figure 21: Energy Sources Used for Heating in the Chris Hani DM

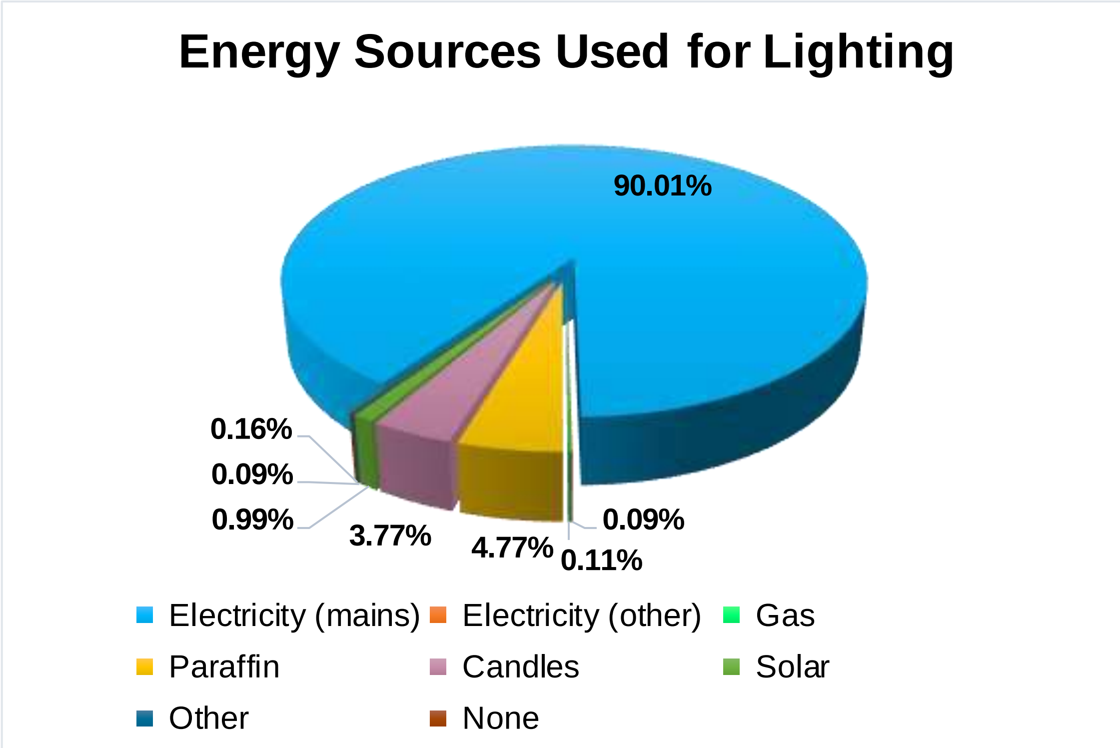

Figure 22: Energy Sources Used for Lighting in the Chris Hani DM

Emissions from domestic burning of paraffin, wood and coal (for cooking, heating and lighting) were calculated, firstly at settlement level and then at municipal level (Table 25, Table 26, Table 27).

Coal burning is the biggest polluter by mass of the fuel burnt in terms of both SO_2 and NO, while wood is the biggest polluter by mass of the fuel burnt in terms of PM_{10}. The relatively large number of households using wood for domestic fuel burning and the relatively high emissions per kilogram of wood burnt (compared to paraffin) leads to wood burning being the largest source of air pollution within the Chris Hani DM in terms of domestic fuel burning (Figure 20, Figure 21, Figure 22 and Figure 23). In total, by mass emitted, PM_{10} is the largest criteria pollutant emitted from domestic fuel burning in the Chris Hani DM (Figure 24).

Table 25: Emissions from domestic burning of paraffin (StatsSA, 2011)

Settlement	Number of Households Using Paraffin	Total Paraffin Usage (kg/year)	Total Emissions from Burning Paraffin (kg/year)		
			SO_2	NO	PM_{10}
Emalahleni LM	5 990	830 597	83.06	1 245.90	166.12
Engcobo LM	5 437	753 916	75.39	1 130.87	150.78
Enoch Mgijima LM	19 401	2 690 220	269.02	4 035.33	538.04
Intsika Yethu LM	9 331	1 293 874	129.39	1 940.81	258.77
Inxuba Yethemba LM	2 973	412 248	41.22	618.37	82.45
Sakhisizwe LM	3 177	440 536	44.05	660.80	88.11
Chris Hani DM	46 309	6 421 391	642	9 632	1 284

Table 26: Emissions from domestic burning of wood (StatsSA, 2011)

Settlement	Number of Households Using Wood	Total Wood Usage (kg/year)	Total Emissions from Burning Wood (kg/year)		
			SO_2	NO	PM_{10}
Emalahleni LM	6 700	1 474 000	294.80	1 916.20	25 500.20
Engcobo LM	10 463	2 301 860	460.37	2 992.42	39 822.18
Enoch Mgijima LM	7 098	1 561 560	312.31	2 030.03	27 014.99
Intsika Yethu LM	10 635	2 339 700	467.94	3 041.61	40 476.81
Inxuba Yethemba LM	2 934	645 480	129.10	839.12	11 166.80
Sakhisizwe LM	3 080	677 600	135.52	880.88	11 722.48
Chris Hani DM	40 910	9 000 200	1 800	11 700	155 703

Table 27: Emissions from domestic burning of coal (StatsSA, 2011)

Settlement	Number of Households Using Coal	Total Coal Usage (kg/year)	Total Emissions from Burning Coal (kg/year)		
			SO_2	NO	PM_{10}
Emalahleni LM	34	40 460	469.34	161.84	485.52
Engcobo LM	48	57 120	662.59	228.48	685.44
Enoch Mgijima LM	136	161 840	1 877.34	647.36	1 942.08
Intsika Yethu LM	73	86 870	1 007.69	347.48	1 042.44
Inxuba Yethemba LM	26	30 940	358.90	123.76	371.28
Sakhisizwe LM	15	17 850	207.06	71.40	214.20
Chris Hani DM	332	395 080	4 583	1 580	4 741

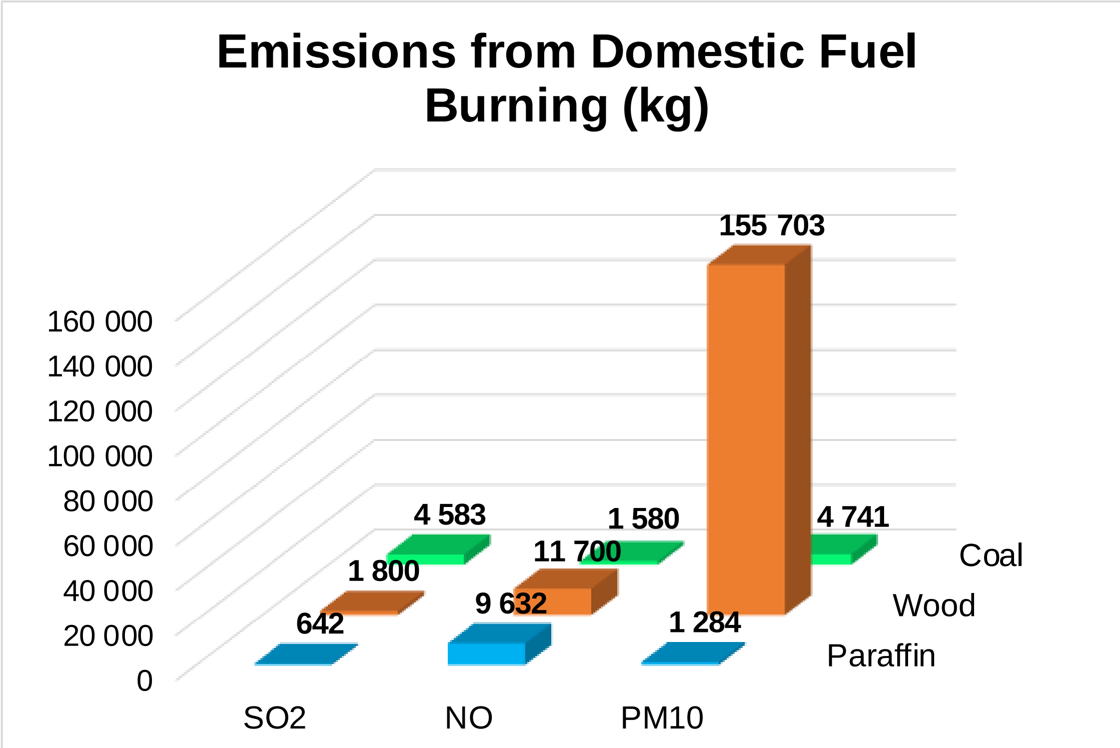

Figure 23: Emissions from domestic fuel burning by fuel type in Chris Hani DM

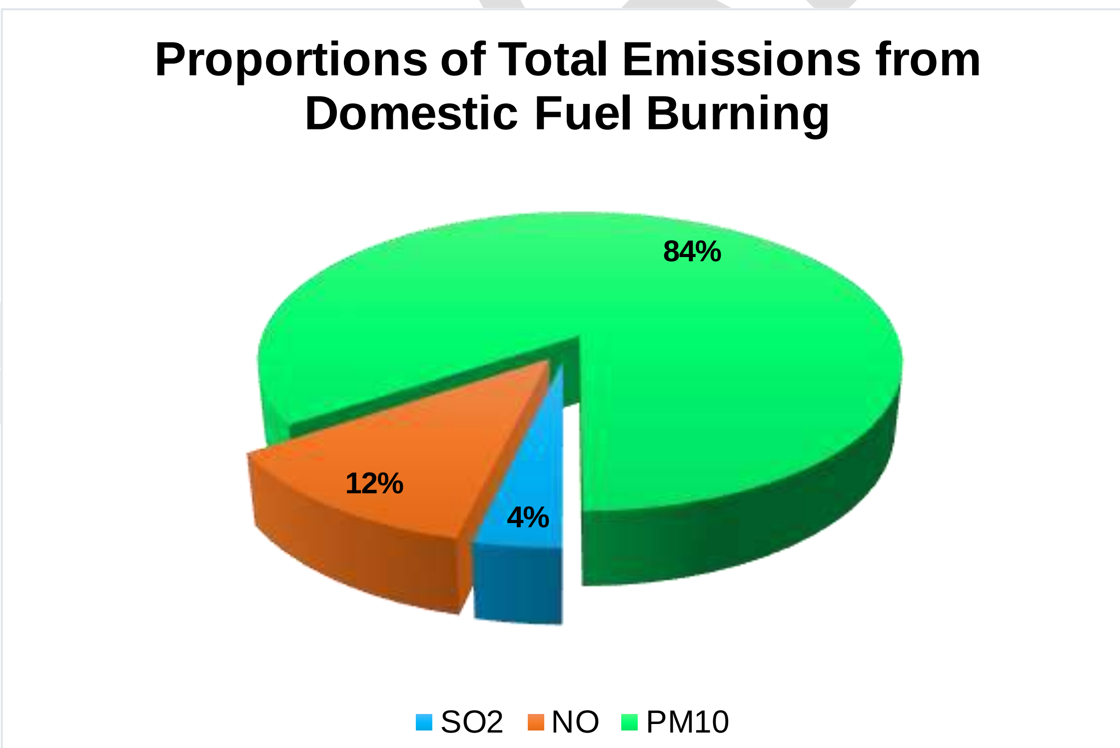

Figure 24: Total domestic fuel burning emissions in the Chris Hani DM

5.3.4. Biomass Burning

The total area burned between 2013 and 2017 in the Chris Hani DM was 543,352.23 ha. This equates to an annual average of 108,607 ha burned. The total emissions over the five years (2013 to 2017), and the annual average emissions were calculated (Table 28).

Table 28: Total emissions from biomass burning in Chris Hani DM

Air pollutant / GHG	Total Emissions [kg] (2013-2017	Annual Average Emissions [kg]
CO	110,493,958	22,098,792
NO_x as NO	6,629,638	1,325,928
SO_2	594,967	118,993
$PM_{2.5}$	9,179,498	1,835,900

Biomass burning is a known seasonal emission; thus, the total burned area between 2013 and 2017 was classified into early and mid-late dry seasons. Approximately 89% of all burned area occurred during the mid-late dry season (Table 29).

Table 29: Seasonal emissions from biomass burning in Chris Hani DM

Air pollutant / GHG	Total Emissions [kg] (2013-2017		Annual Average Emissions [kg]	
	Mid-Late Dry Season	Early Dry Season	Mid-Late Dry Season	Early Dry Season
CO	104,268,655	6,225,303	20,853,731	1,245,061
NO_x as NO	6,256,119	373,518	1,251,224	74,704
SO_2	561,447	33,521	112,289	6,704
$PM_{2.5}$	8,662,319	517,179	1,732,464	103,436

The burned area from 2013 to 2017 was further analysed based on the type of landcover was burned. The burned area was correlated with the DEA 2014 Landcover dataset. This analysis indicates that 79.16% of the burned area occurred in grasslands. The low shrubland landcover type was the second highest contributor to biomass burning with 7.43%. The third highest contributor was the Thicket / Dense Bush landcover class, with 3,4%. These three landcover categories accounted for 90% of all burned area between 2013 and 2017.

5.3.5. Agricultural Activities

(a) Crop Farming

Emissions from agricultural activities (excluding livestock processes) occur from fertilizer application, soil cultivation, harvesting, cleaning and drying for all crop types. Crops identified in the Chris Hani DM include maize, wheat, lucerne, potatoes, oranges and naartjies. Emissions were calculated for the land preparation and harvesting of these crops.

A total of approximately 3.53 million kilograms of nitrogen fertilizer is applied for agricultural activities per annum. Sakhisizwe LM utilizes the most fertilizer per annum (Figure 25). The application of fertilizer equates to over 61 thousand kilograms of PM_{10} emissions per annum (Table 30). Additional emissions from fertilizer application include NO, NH_3 and $PM_{2.5}$.

Table 30: Emission from Fertilizer Application

Municipality	Fertilizer Applied (kg)	Area Fertilized (ha)	Emissions from Fertilizer Application (kg)			
			NO	NH_3	PM_{10}	$PM_{2.5}$
Emalahleni LM	4 340	201	174	217	313	12
Enoch Mgijima LM	631 795	7 538	25 272	31 590	11 759	452
Intsika Yethu LM	50 200	2 355	2 008	2 510	3 675	141
Inxuba Yethemba LM	548 184	12 450	21 927	27 409	19 422	747
Sakhisizwe LM	2 298 629	16 745	91 945	114 931	26 123	1 005
Total	**3 533 147**	**39 289**	**141 326**	**176 657**	**61 291**	**2 357**

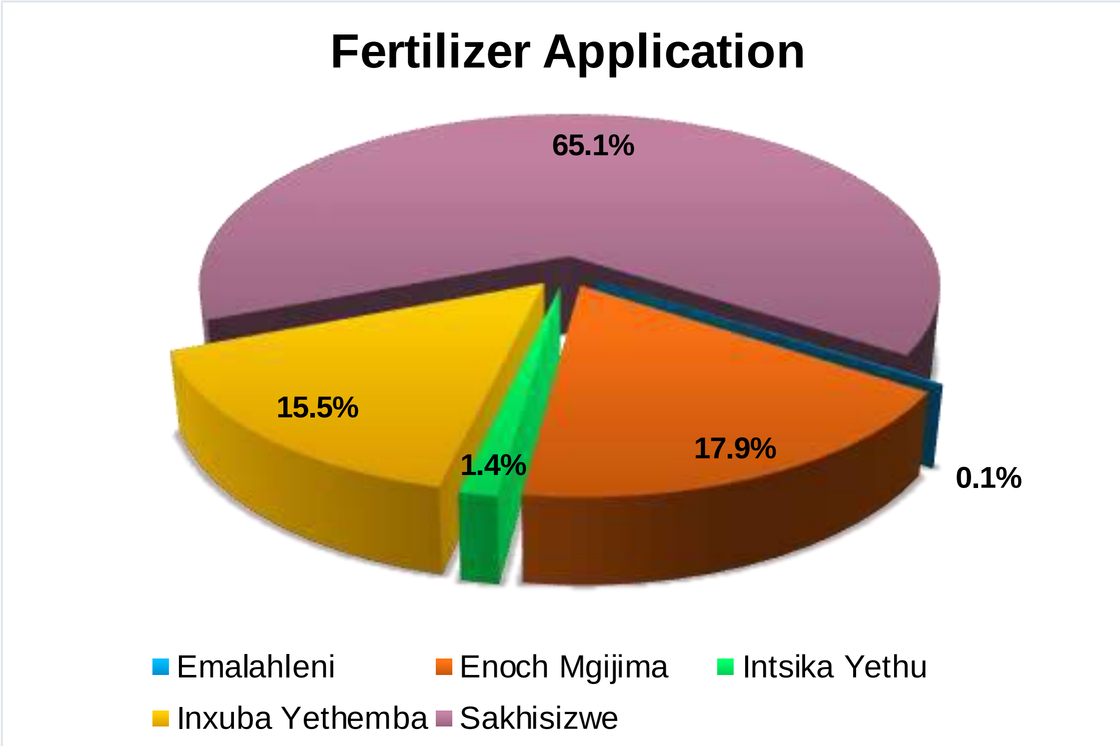

Figure 25: Proportions of fertilizer application per Local Municipalities within Chris Hani DM

Emissions from crop farming were calculated by crop and by Municipality (Table 31). Sakhisizwe LM has the largest area of land used for crop farming (Figure 28) and hence the highest emissions (Figure 26 and Figure 27). Potatoes account for the largest area planted in the Municipality (39.56%) followed by Lucerne (32.43%) (Figure 29).

Table 31: Total particulate matter emissions from agricultural crops

Emissions by Crop (kg)			Emissions by Municipality (kg)		
Crop	**PM_{10}**	**$PM_{2.5}$**	**Municipality**	**PM_{10}**	**$PM_{2.5}$**
Maize	73 539	16 296	Emalahleni LM	1 541	267
Wheat	6 298	1 397	Engcobo LM	-	-
Lucerne	92 667	15 158	Enoch Mgijima LM	111 996	23 747
Potatoes	446 912	99 278	Intsika Yethu LM	17 689	3 125
Oranges	0	0	Inxuba Yethemba LM	120 654	23 504
Naartjies	0	0	Sakhisizwe LM	367 534	81 487
Total	**619 415**	**132 129**	**Total**	**619 415**	**132 129**

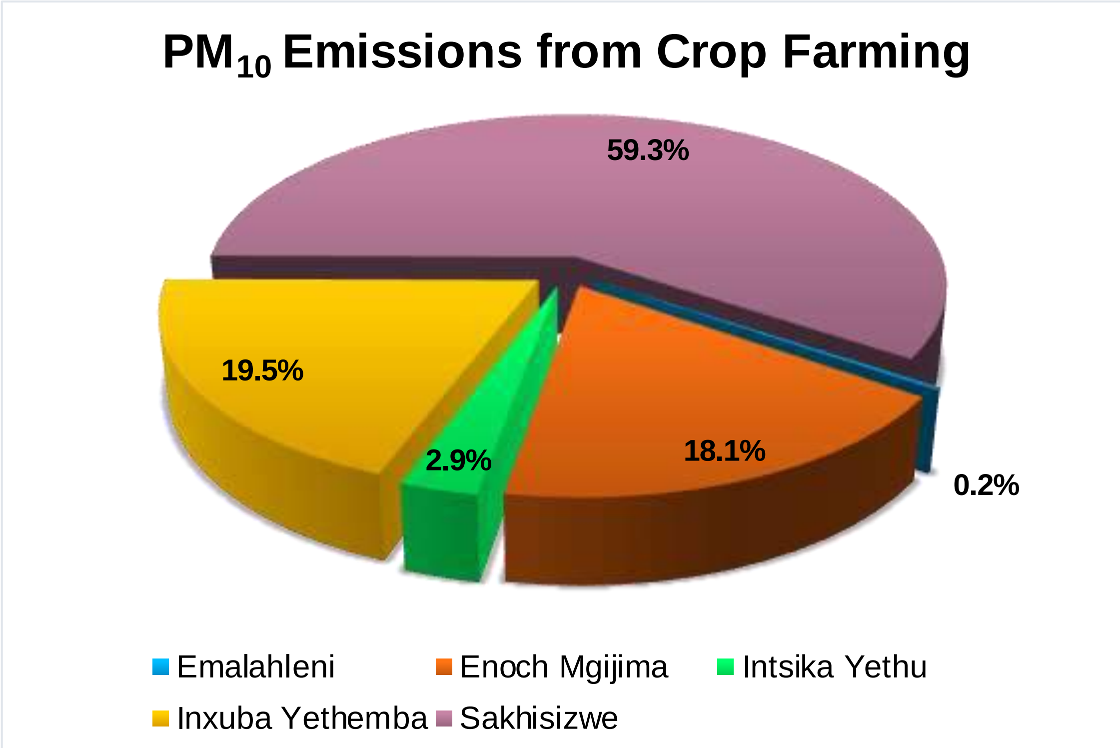

Figure 26: PM_{10} emissions from crop farming in Chris Hani DM

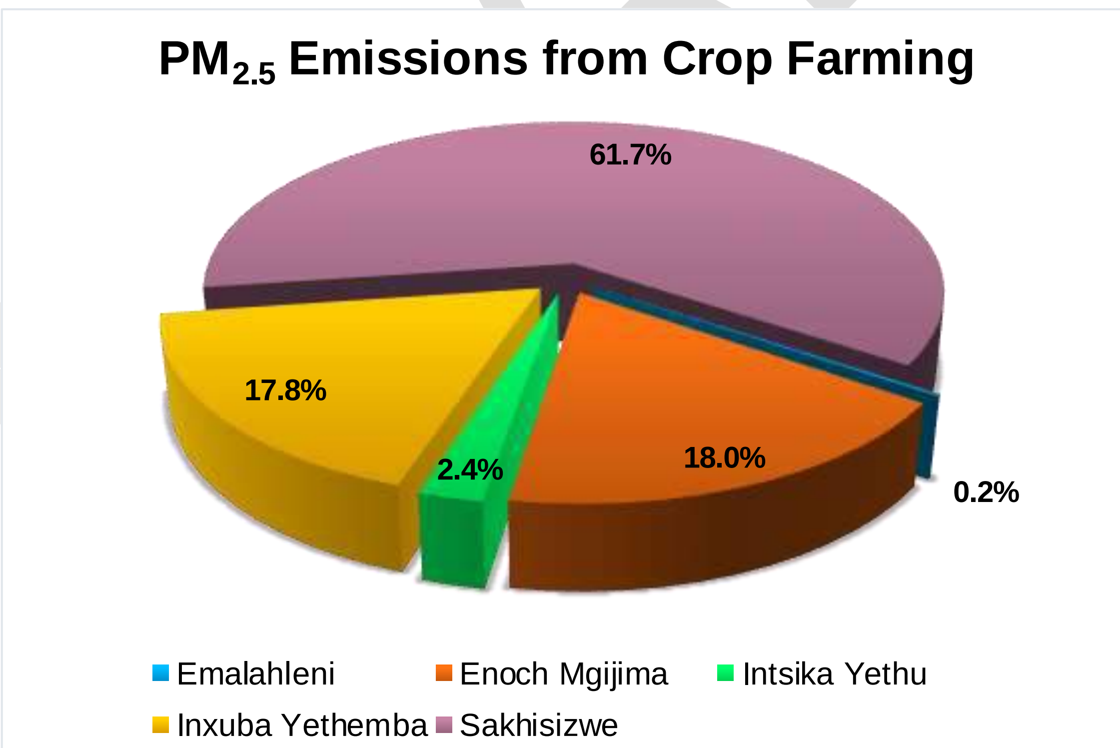

Figure 27: $PM_{2.5}$ emissions from crop farming in Chris Hani DM

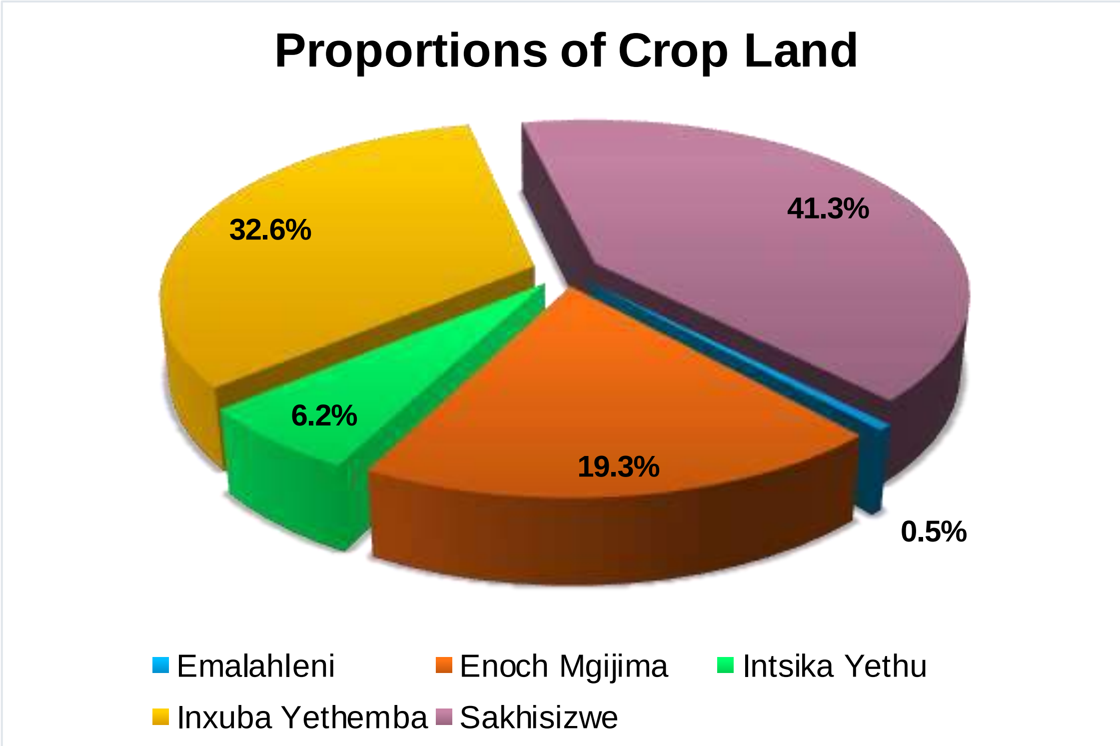

Figure 28: Proportions of Crop Land per Local Municipality within Chris Hani DM

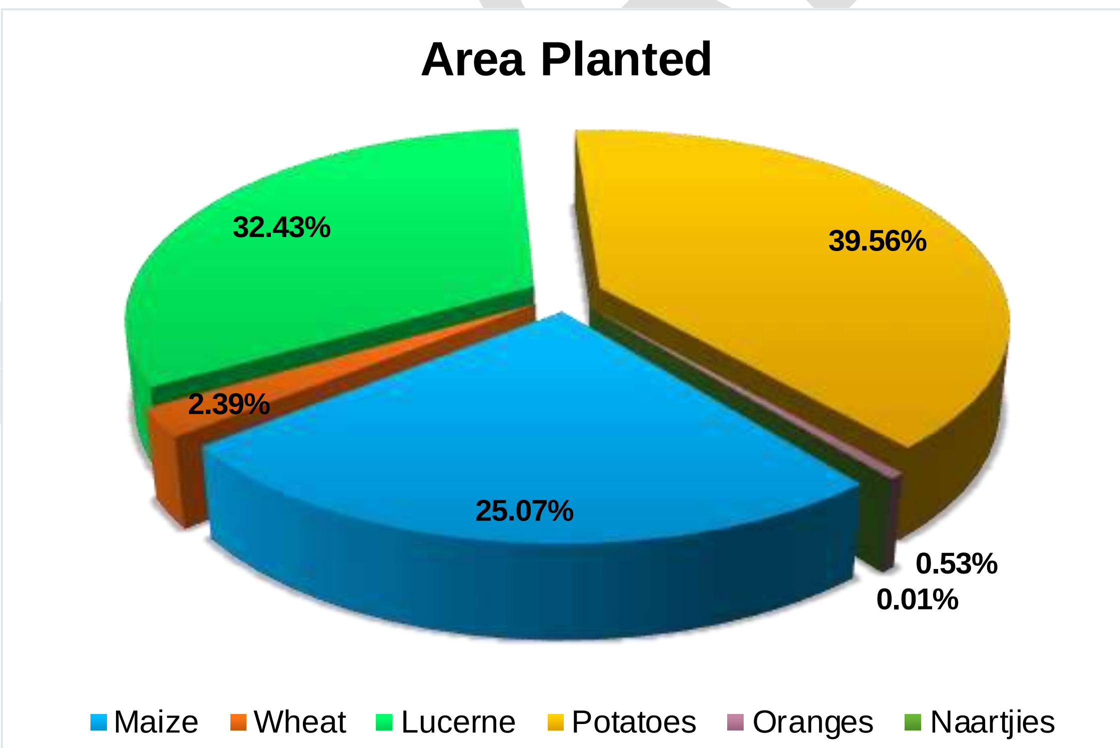

Figure 29: Proportions of the area planted per crop in Chris Hani DM

(b) Livestock Farming

Emissions from livestock farming were calculated at commercial area level and subsequently at District level (Table 32). The largest contributions to PM emissions from livestock in Chris Hani DM are made by Enoch Mgijima LM followed by Inxuba Yethemba LM (Figure 30 and Figure 31). This is due to the relatively high number of commercial livestock farmed in these municipalities (Figure 32).

Table 32: Total emissions from livestock

Municipality	Commercial Area	Number of Heads			Estimated Emissions (kg/year)	
		Goats	Sheep	Cattle	PM_{10}	$PM_{2.5}$
Emalahleni LM	Indwe	67	53 579	14 125	9 575.01	5 239.80
Enoch Mgijima LM	Hofmeyr	1 110	72 191	4 109	6 247.11	2 678.18
	Molteno	1 988	102 257	16 051	13 477.65	6 819.95
	Queenstown	7 155	104 386	34 545	22 237.71	12 421.60
	Sterkstroom	4 056	81 515	17 665	13 083.51	6 922.60
	Tarka	8 160	177 401	22 122	21 088.56	10 237.21
Intsika Yethu LM	Wodehouse	352	186 972	34 760	26 881.44	14 000.68
Inxuba Yethemba LM	Cradock	32 974	167 804	22 737	22 278.33	10 722.98
	Middelburg	4 959	152 624	9 504	13 731.78	5 955.34
Sakhisizwe LM	Elliot	336	179 929	34 095	26 158.65	13 663.33
Total		61 157	1 278 658	209 713	174 759.75	88 661.64

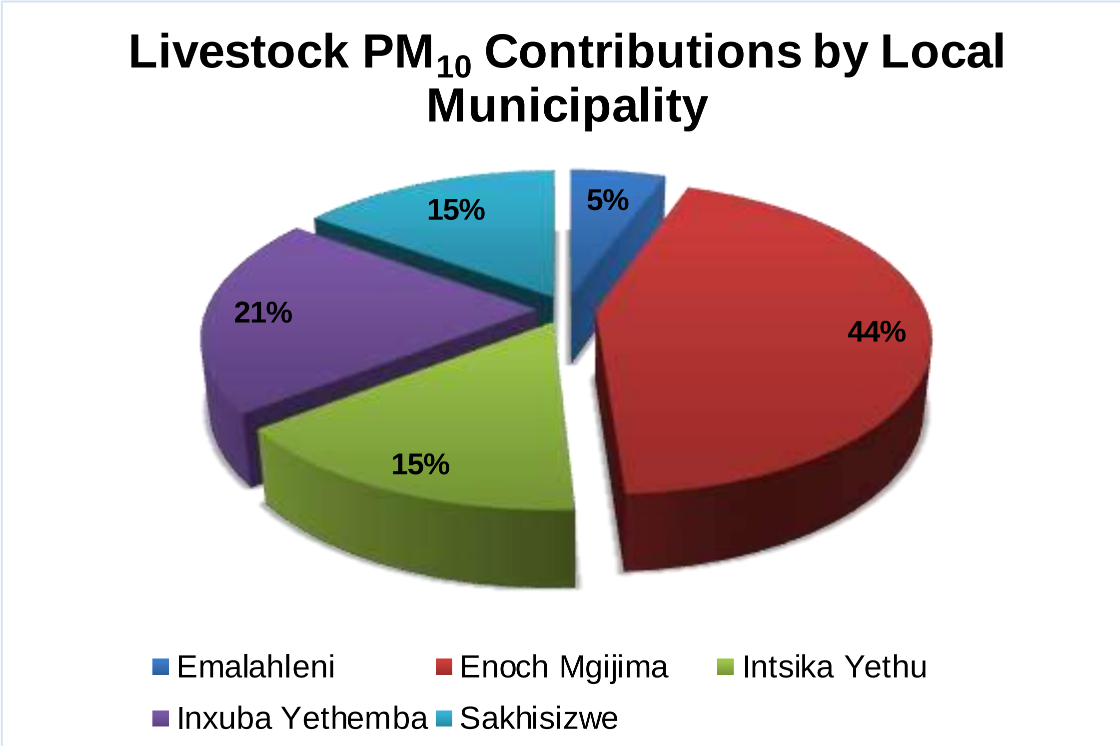

Figure 30: PM_{10} emissions from livestock farming in Chris Hani DM

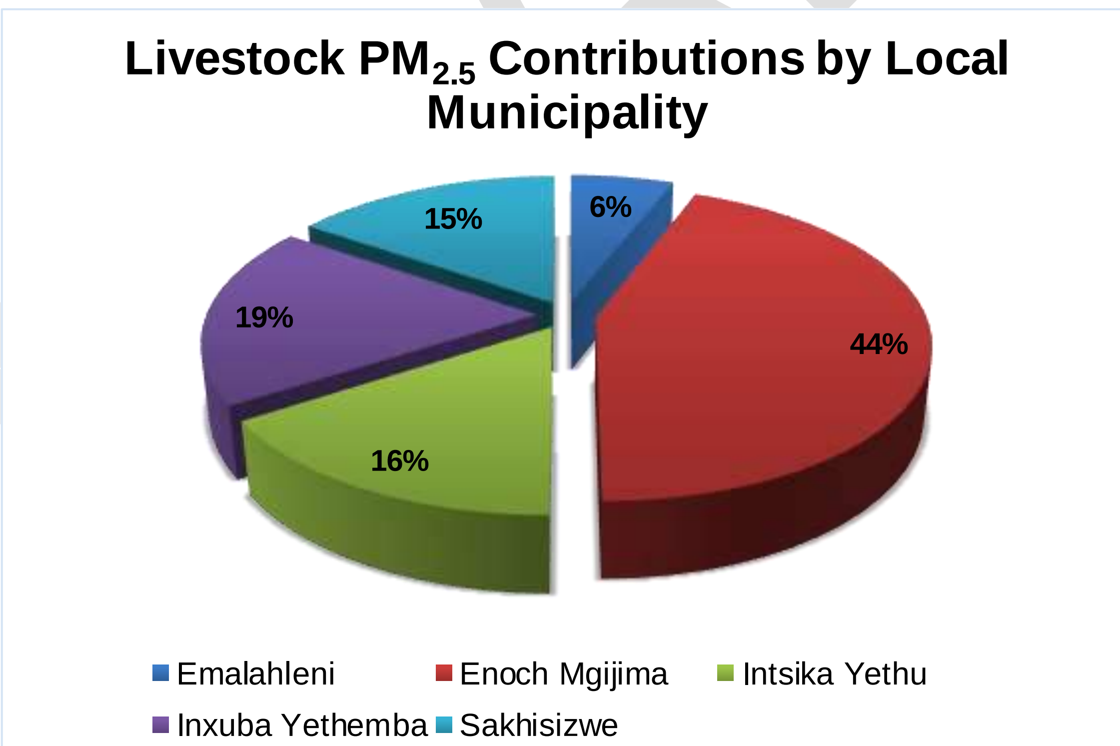

Figure 31: $PM_{2.5}$ emissions from livestock farming in Chris Hani DM

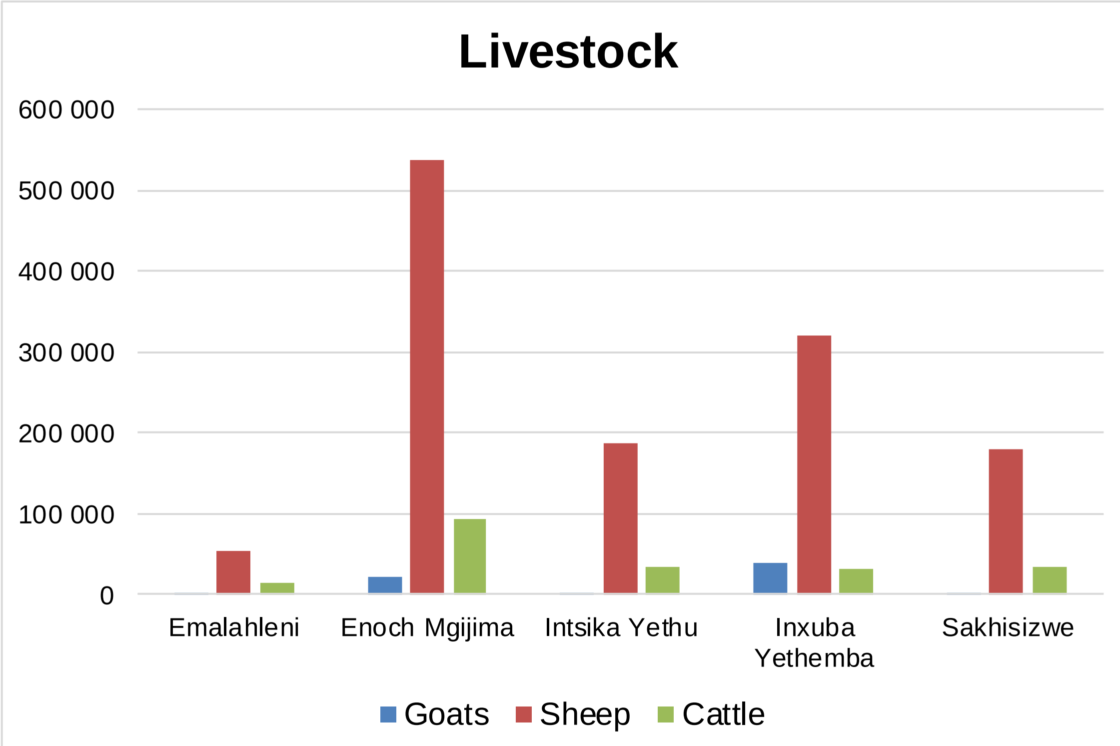

Figure 32: Number of commercial livestock in the Local Municipalities within Chris Hani DM

5.3.6. Denuded Land

Denuded land in Chris Hani DM contributes approximately 125 metric tons of PM_{10} emissions and 19 metric tons of $PM_{2.5}$ emissions (Table 33). The $PM_{2.5}$ emissions are significantly lower than the PM_{10} emissions, possibly due to the fact that the smaller particles have been removed more easily in the beginning leaving only coarser material available to be entrained by wind action. For the Maricopa County study (2011), $PM_{2.5}$ emissions were assumed to be 15% of the PM_{10} emissions. Inxuba Yethemba has the greatest area of denuded land (75%) followed by Enoch Mgijima LM (18%) (Figure 33).

Table 33: Denuded land particulate emissions in Chris Hani DM

Municipality	Area of Degraded Land (km^2)	Estimated Emissions (metric tons/year)	
		PM_{10}	$PM_{2.5}$
Emalahleni LM	7.48	2.69	0.40
Engcobo LM	7.19	2.59	0.39
Enoch Mgijima LM	60.51	21.78	3.27
Intsika Yethu LM	5.01	1.80	0.27
Inxuba Yethemba LM	258.05	92.90	13.93
Sakhisizwe LM	8.11	2.92	0.44
Chris Hani DM	**346.35**	**124.69**	**18.70**

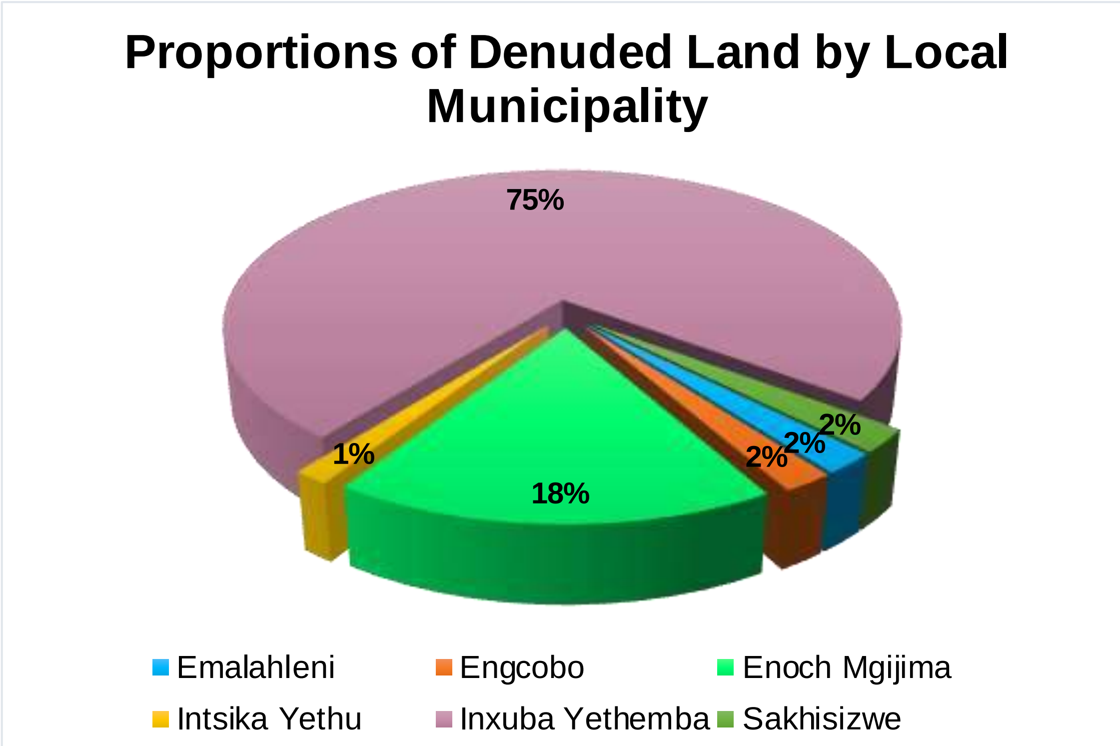

Figure 33: Proportions of denuded land within the Local Municipalities in Chris Hani DM

5.3.7. Mining

The Chris Hani DM has some mining areas covering approximately 8.22 km^2 (Table 34). These mining activities contribute approximately 5 thousand metric tons of PM_{10} emissions and 1 thousand metric tons of $PM_{2.5}$ emissions. Enoch Mgijima LM has the greatest area of land mined within Chris Hani DM (39%) followed by Inxuba Yethemba LM (36%) (Figure 34).

Table 34: Particulate emissions from mining in Chris Hani DM

Municipality	Mining Area (km^2)	Estimated Emissions (metric tons/year)	
		PM_{10}	$PM_{2.5}$
Emalahleni LM	0.34	195.37	46.28
Engcobo LM	0.38	220.51	52.23
Enoch Mgijima LM	3.22	1 875.62	444.30
Intsika Yethu LM	0.43	247.74	58.69
Inxuba Yethemba LM	2.99	1 740.49	412.29
Sakhisizwe LM	0.87	504.91	119.61
Chris Hani DM	**8.22**	**4 784.64**	**1 133.39**

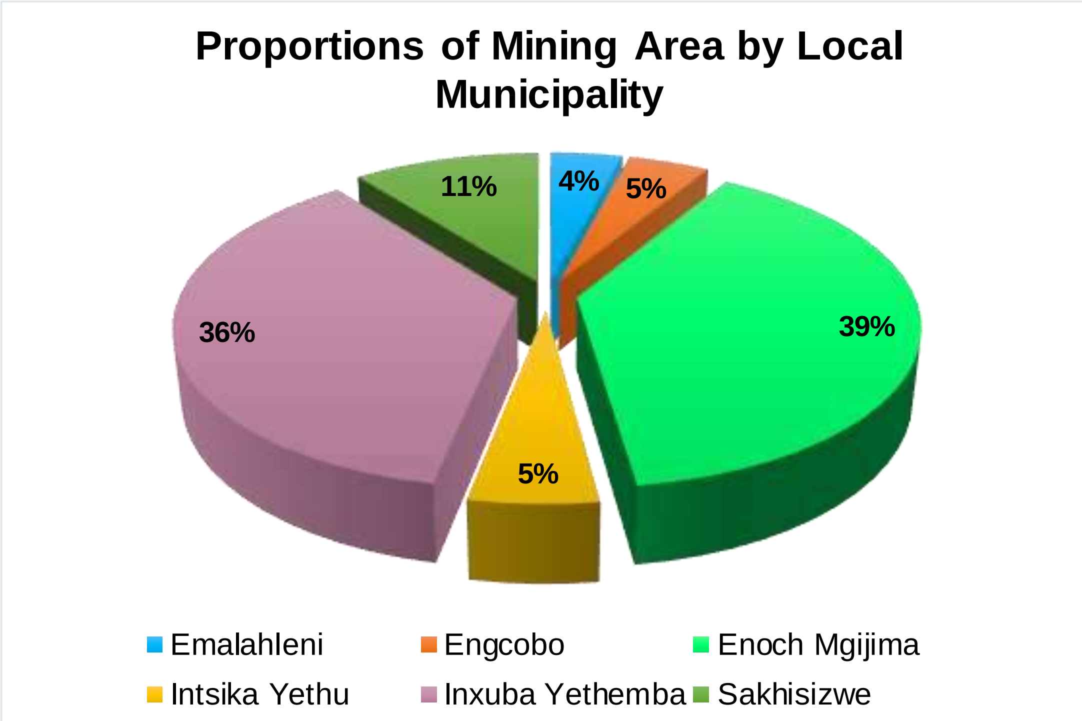

Figure 34: Proportions of mining land within the Local Municipalities in Chris Hani DM

5.3.8. Landfills

Landfills are known to emit substantial amounts of pollutants which can be harmful to human health and the environment. Benzene emissions from the landfills in Chris Hani DM are estimated to be 7 920 kg/year and PM_{10} emissions to be 2 928 kg/year (Table 35).

Table 35: Emissions from landfills in Chris Hani DM

Municipality	Town	Estimated Emissions (kg/year)	
		Benzene	PM_{10}
Emalahleni LM	Dordrecht	660	244
	Indwe	660	244
	Lady Frere	660	244
Engcobo LM	Engcobo	660	244
Enoch Mgijima LM	Queenstown	660	244
	Tylden	660	244
	Whittlesea	660	244
Intsika Yethu LM	Cofimvaba	660	244
	Tsomo	660	244
Inxuba Yethemba LM	Cradock	660	244
	Middelburg	660	244
Sakhisizwe LM	Elliot	660	244
Total		7 920	2 928

5.3.9. Wastewater Treatment Works

There are 16 WWTW in Chris Hani DM. These treat approximately 16 056 554 m^3/year and produce approximately 17 thousand kg of VOC emissions per year (Table 36). Of the wastewater treated in Chris Hani DM, 65% is treated within the Enoch Mgijima LM (Figure 35).

Table 36: VOC emissions from wastewater treatment works in Chris Hani District Municipality.

Municipality	WWTW	Volume Treated (m^3/year)	Estimated VOC Emissions (kg/year)
Emalahleni LM	Dordrecht	438 000	468.66
	Indwe	365 000	390.55
	Lady Frere	292 000	312.44
Engcobo LM	Engcobo	182 500	195.28
Enoch Mgijima LM	Hofmeyr	14 600	15.62
	Molteno	1 262 900	1 351.30
	Queenstown	6 898 734	7 381.64
	Sada	1 825 000	1 952.75
	Sterkstroom	405 150	433.51
	Tarkastad	62 050	66.39
Intsika Yethu LM	Cofimvaba	474 500	507.72
	Tsomo	73 000	78.11
Inxuba Yethemba LM	Cradock	1 605 971	1 718.39
	Middelburg	1 460 000	1 562.20
Sakhisizwe LM	Cala	109 500	117.17
	Elliot	587 650	628.79
Total		**16 056 554**	**17 180.51**

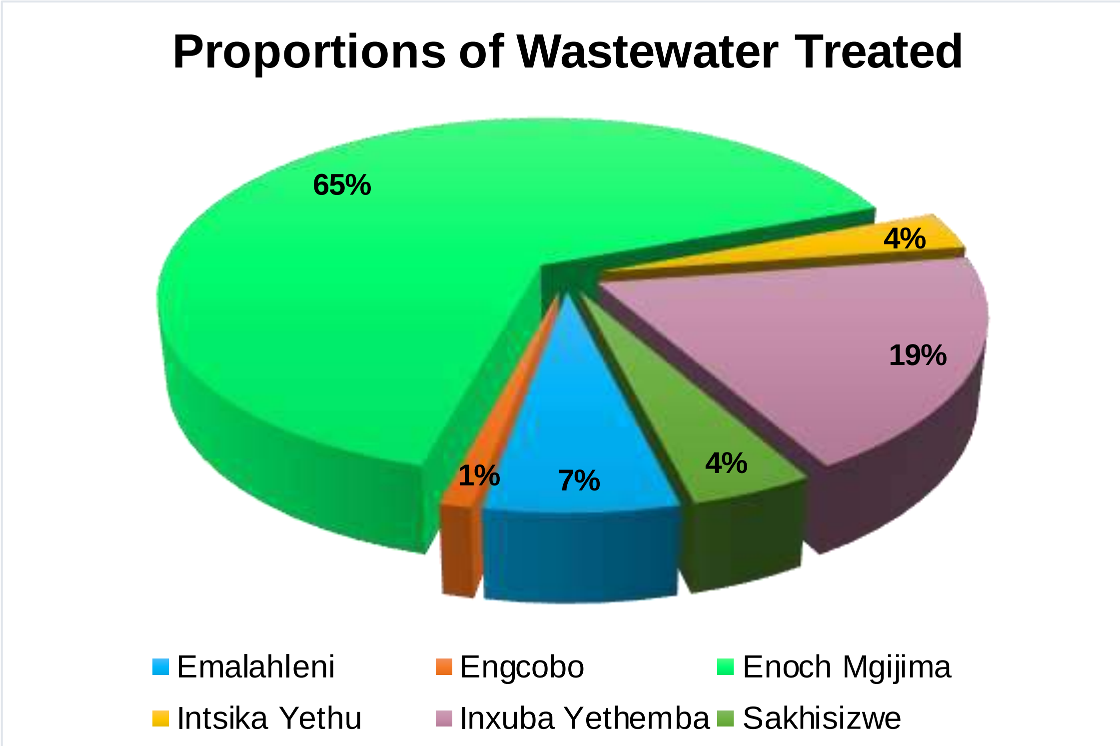

Figure 35: Proportions of wastewater treatment capacity of the WWTW in Chris Hani DM

5.3.10. Summary of Emissions in the Chris Hani DM

A summary of the emissions from all the sources in the Chris Hani DM is presented (Table 37). By mass, CO is the largest pollutant emitted within Chris Hani DM followed by PM_{10}, $PM_{2.5}$ and NO_X. Biomass burning operations emit 96.7% of the CO emissions within the municipality (Figure 39). Biomass burning and vehicles also contributes the highest levels of SO_2 (49.8% and 47.2% respectively) followed by domestic fuel burning (2.9%) (

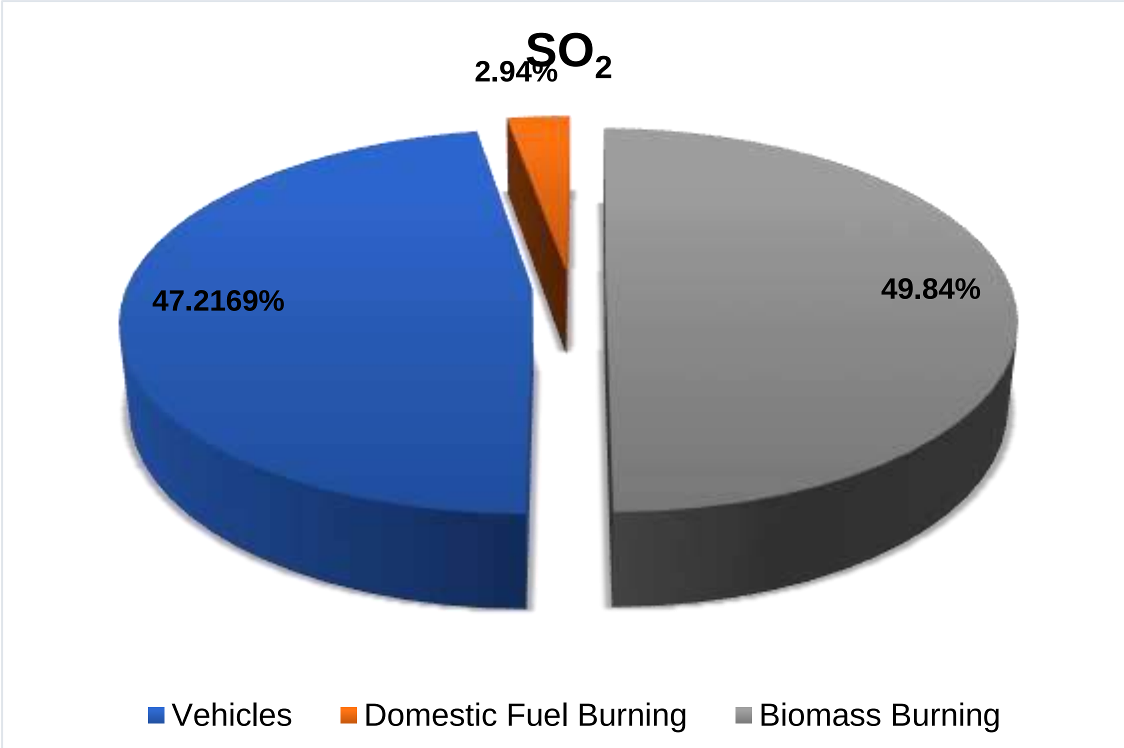

Figure 38). In this study, the only calculated source of lead emissions was the vehicle sector. It should be noted that PM_{10} emissions have been underestimated in this study as the $PM_{2.5}$ emitted by biomass burning contributes to the PM_{10} emissions from this sector even though PM_{10} emissions from biomass burning has not been explicitly calculated. In addition, PM emissions from vehicles have not been calculated as this will depend on the types of vehicles as well as the quality of roads in the municipality.

Table 37: Summary of criteria pollutant emissions from all sources in the Chris Hani DM

Sector	Pollutant (metric tons/year)							
	PM_{10}	$PM_{2.5}$	SO_2	NO_x	VOCs	CO	Lead	Total
Listed Activities	1.43	1.43	-	2.46	1.34	0.09	-	6.75
Small Boilers	0.45	0.18	6.61	1.13	0.57	-	-	8.94
Vehicles	-	-	112.73	938.38	0.90	738.20	46.10	1 836.31
Domestic Fuel Burning	161.73	-	7.03	22.91	-	-	-	191.67
Biomass Burning	1 835.90	1 835.90	118.99	1 325.93	-	22 098.79	-	27 215.51
Agriculture	855.47	223.15	-	141.33	-	-	-	1 219.94
Denuded Land	124.69	18.70	-	-	-	-	-	143.39
Mining	4 784.64	1 133.39	-	-	-	-	-	5 918.04
Landfills	2.93	-	-	-	7.92	-	-	10.85
WWTW	-	-	-	-	17.18	-	-	17.18
TOTAL	7 767.23	3 212.75	245.36	2 432.14	27.91	22 837.08	46.10	36 568.57

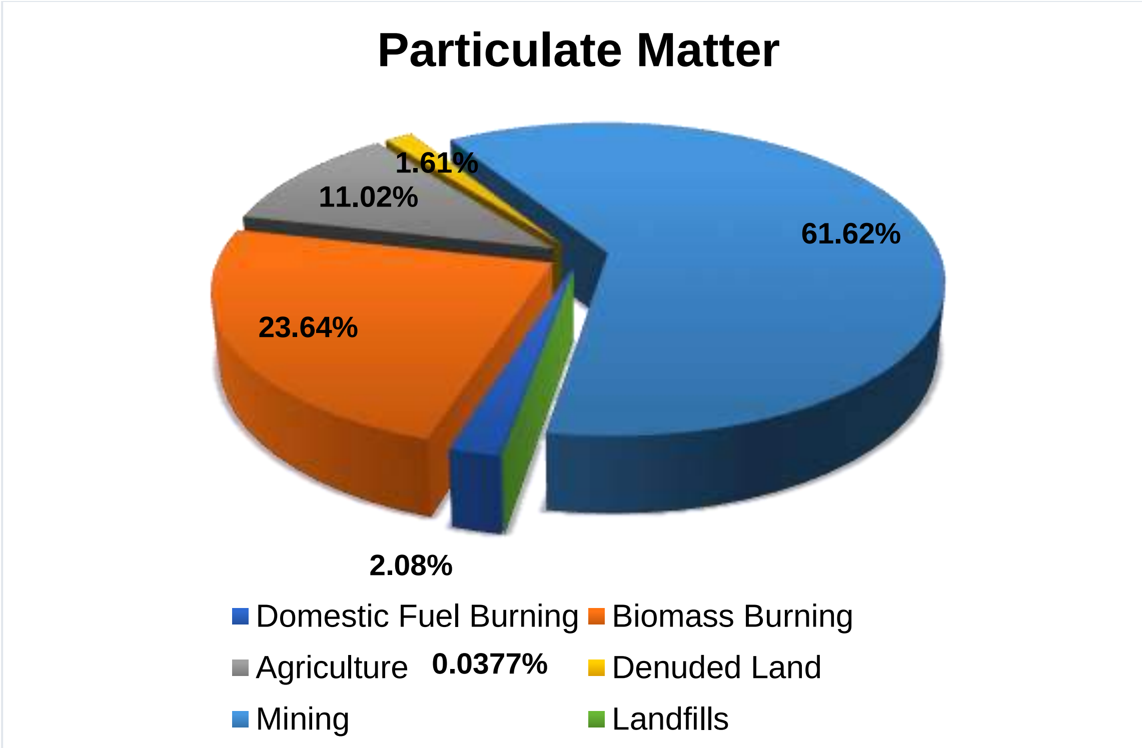

Figure 36: Contribution of sectors to total Particulate Matter emissions in the Chris Hani DM

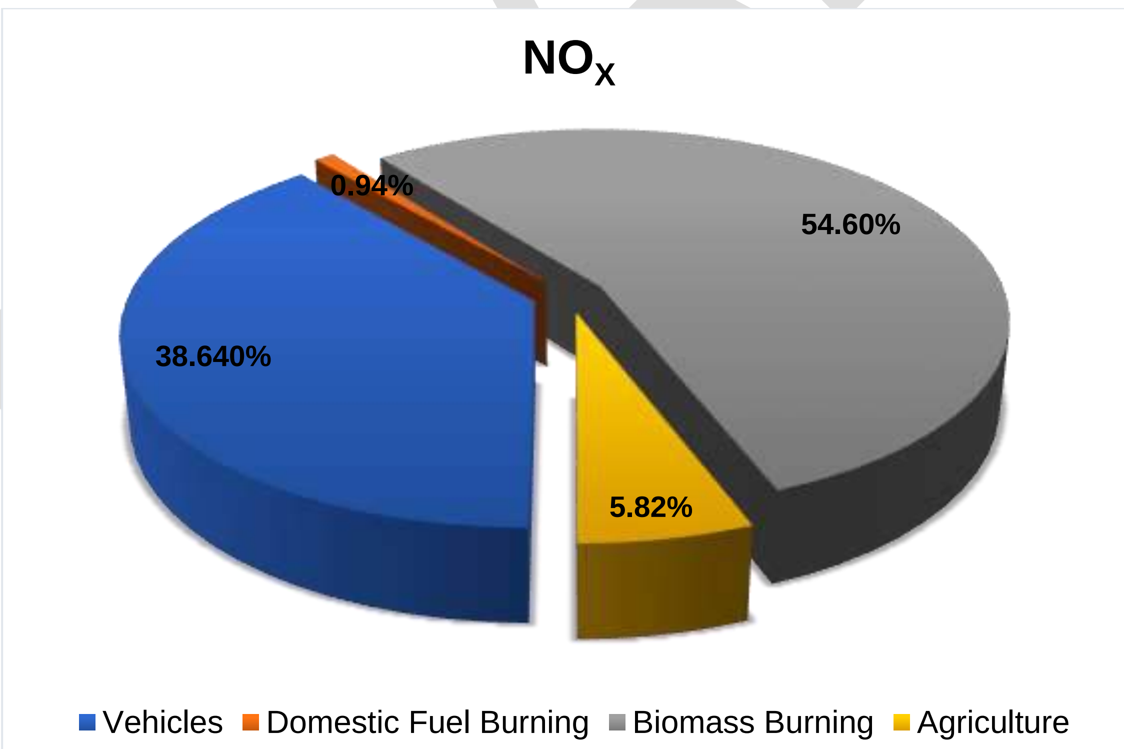

Figure 37: Contribution of sectors to total NO_X emissions in the Chris Hani DM

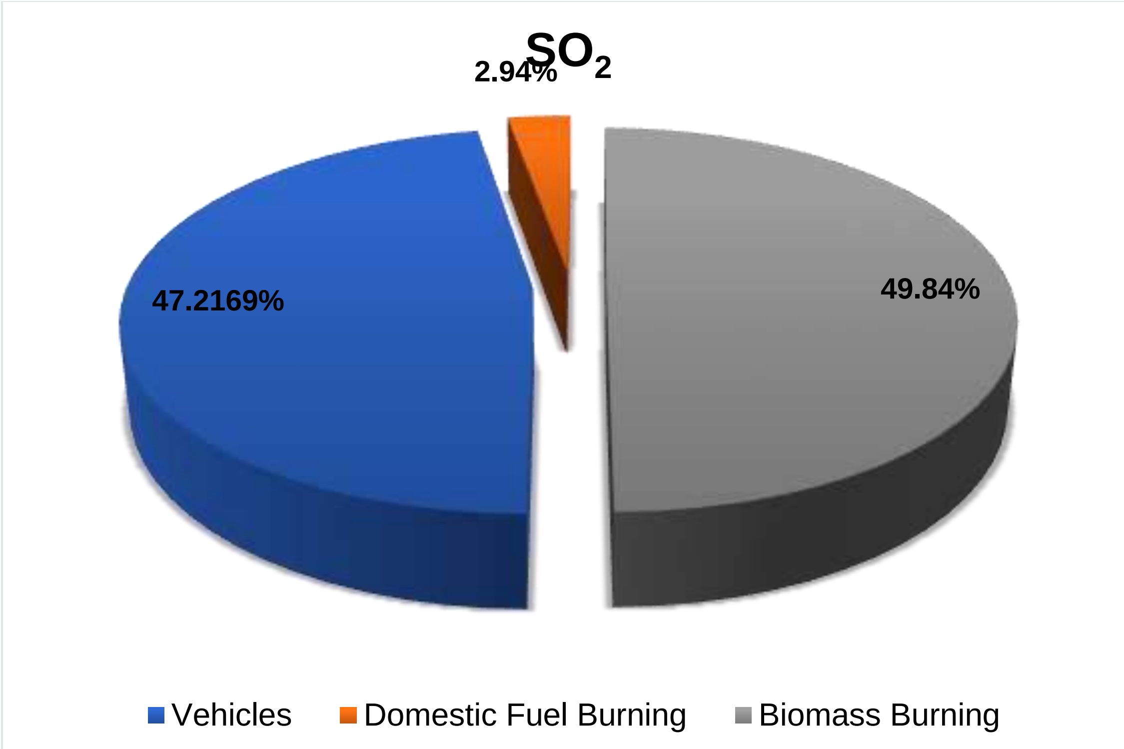

Figure 38: Contribution of sectors to total SO_2 emissions in the Chris Hani DM

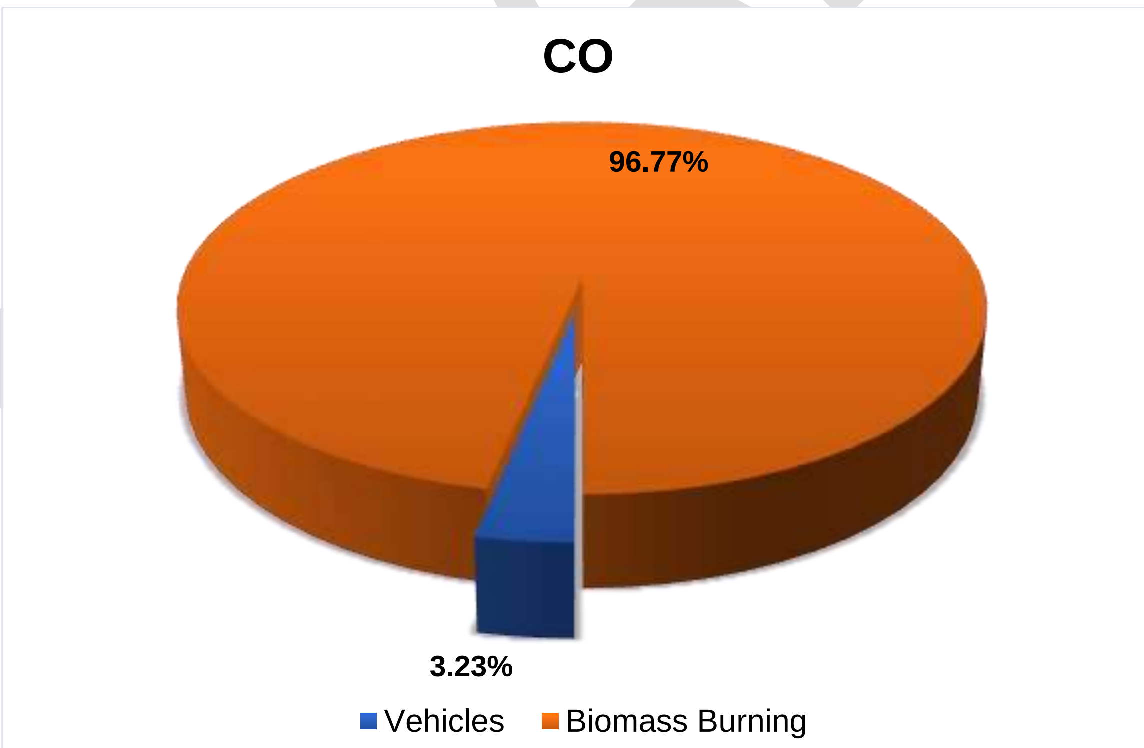

Figure 39: Contribution of sectors to total CO emissions in the Chris Hani DM

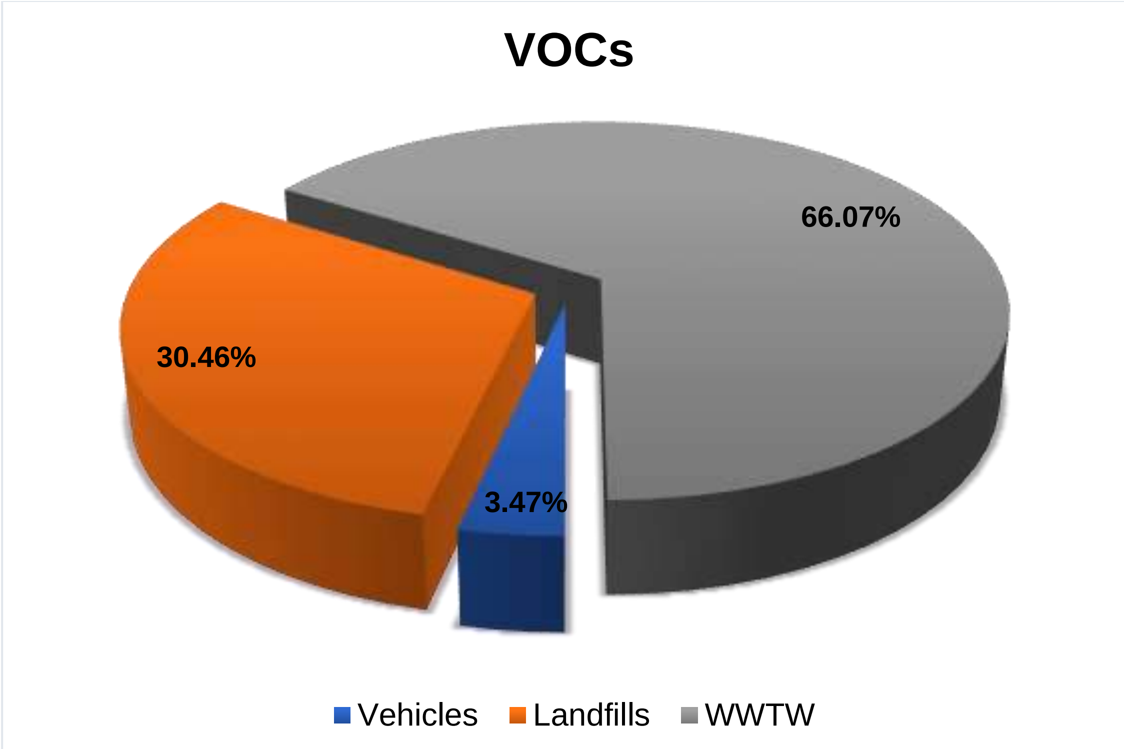

Figure 40: Contribution of sectors to total VOC emissions in the Chris Hani DM

6. AIR QUALITY PRACTICES AND INITIATIVES WITHIN PROVINCIAL AND LOCAL GOVERNMENT

6.1. Government Structure and Functions

In this section, the capacity for air quality management and control within the Bushbuckridge LM is assessed within the various spheres of Government.

6.1.1. Provincial Level

Within the Eastern Cape Province, the Department of Economic Development, Environmental Affairs & Tourism (DEDEAT) is responsible for air quality related functions. The DEDEAT supports the functions of Local and District Municipalities and plays an oversight role within the Province. In particular, the DEDEAT assists all of the district municipalities in the Province with their AEL function (uMoya-NILU, 2013).

A Provincial AQO has been designated by the DEDEAT (uMoya-NILU, 2013). The AQO is responsible for the coordination of all air quality related matters within the province. This includes oversight of the development of Provincial strategies and policies.

6.1.2. District Level

Within the Chris Hani DM, the Health and Community Services Department is responsible for air quality management. No dedicated AQO had been appointed at the time of this report (Figure 41). Air quality functions therefore form part of the duties of the two Environmental Control Officers (ECOs) desiginated by the Municipality.

6.1.3. Local Level

There are no dedicated Air Quality Officers at local level.

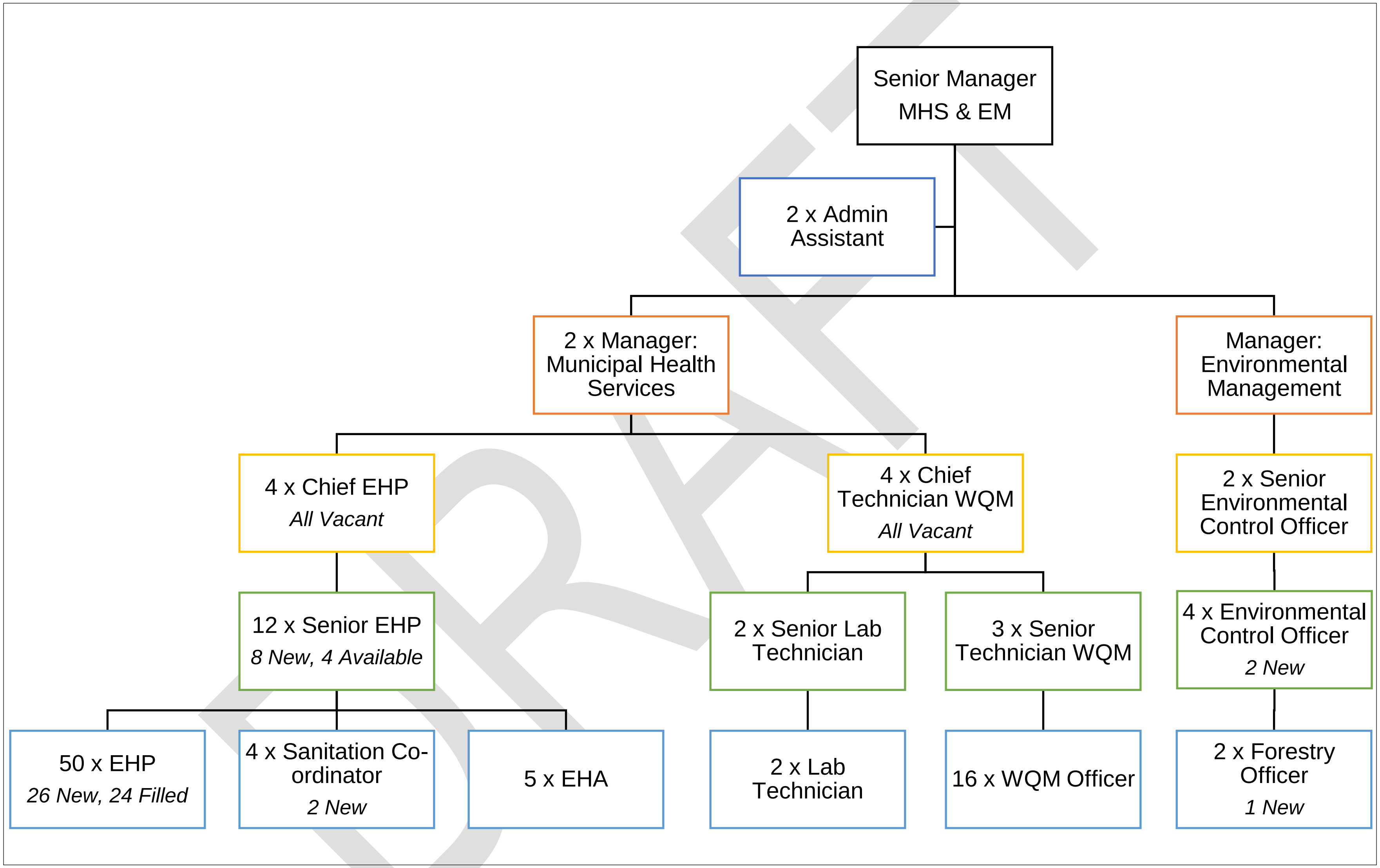

Figure 41: Chris Hani DM Health and Community Services – Municipal Health Services and Environmental Management Organogram

6.2. Air Quality Management Tools

6.2.1. Complaints Response Database

Air pollution complaints received from the public need to be recorded in a database, investigated and addressed within each level of Government. Pollution complaints need to be logged into a centralised electronic pollution complaints database at provincial level to ensure the effective co-ordination and management of complaints received. Complaints reported to the National Department of Environmental Affairs (DEA) are referred back to the Chris Hani DM.

Prior to such a system being implemented, it is recommended that the Chris Hani DM maintain a complete complaints system, keeping records of responses, letters, notices and feedback to the complainant. Complaints should be recorded based on the complaint type such as smoke, odours, dust etc. and be dealt with accordingly. In terms of compliance and enforcement, verbal warnings are generally issued and, for more serious offences, written notices are served.

6.2.2. Emissions Inventory Database

For effective air quality management and control, an accurate, electronic emissions inventory of point, non-point and mobile sources must be established. The emissions inventory should include information on source parameters (source location, stack height, stack diameter, exit gas velocity, exit temperature, etc.) and associated pollutant emission rates. An emissions inventory serves the function of

- providing spatially resolved source strength data on each pollutant for dispersion modelling,
- predicting environmental impacts,
- helping in urban and regional planning,
- supporting the design of regional monitoring networks,
- contributing a basis for evaluating trends, and
- assisting in the formulation of air quality management policies.

Chris Hani DM initiated the process of developing an emissions inventory by setting up a list of companies that may contribute to air pollution along with details regarding each company. Building upon this knowledge, a preliminary emissions inventory database has been established as part of the Status Quo Assessment (Section 5). This information will need to be verified and updated by the Eastern Cape Province and Chris Hani DM.

It is not necessary for the Chris Hani DM to purchase emissions inventory software; use can be made of available software such as Microsoft Excel or Microsoft Access to capture the emissions inventory information supplied by industries. The Chris Hani DM will need to ensure that their current emissions inventory database is regularly updated and that it is incorporated into the South African Air Quality Information System (SAAQIS).

As part of the South African Air Quality Information System phase two, all source and emissions data recorded within each Municipality and Province should be incorporated into a National Atmospheric Emissions Inventory System (NAEIS), allowing for easy access and manipulation of data from any sphere of Government. Since NAEIS was established, Atmospheric Emissions License holders have had to submit annual emissions inventory reports for the compilation of a National emission inventory profile (Government Notice No. 893, 2013).

6.2.3. Dispersion Modelling Software

Limited software and knowledge exists within each sphere of Government to support dispersion modelling. Dispersion modelling software is not available at either the Local, or District level. When required, dispersion modelling is undertaken by external consultants. The use of such modelling software is critical to the understanding of the temporal and spatial distribution of pollutants in the atmosphere.

Atmospheric dispersion modelling forms an integral component of air quality management and planning. Air quality models are used to establish a relationship between emissions and air quality. Dispersion models require the input of data which includes

- meteorological conditions such as wind speed and direction, the amount of atmospheric turbulence, ambient air temperature and the height to the bottom of any inversion layers in the upper atmosphere,
- emission parameters such as source location and height, stack diameter, exit gas temperature and exit velocity,
- terrain elevations at the source and surrounding regions, and
- the location, height and width of any obstructions (such as buildings).

Dispersion modelling is typically used to determine compliance with ambient air quality guidelines or standards and assist in health and environmental risk assessments. It also provides information for the positioning of ambient air quality monitoring networks and helps to assess source contributions to ambient air quality concentrations.

The Department of Environmental Affairs (DEA) has developed Air Dispersion Modelling Regulations and technical guidance under paragraph (p) of section 53 of the AQA to ensure that that dispersion modelling practices throughout South Africa are standardised.

6.2.4. Data Monitoring and Reporting Practices

Currently there are no ambient air quality monitoring stations in the Chris Hani DM (DEA, 2018). The co-ordinated transfer of data from the monitoring stations to a centralised database is critical to ensure the effective and efficient management and verification of the monitoring data. As part of the South African Air Quality Information System (SAAQIS), a centralised database has been developed at the South African Weather Services to which all ambient monitoring data is transferred. This database is useful for ensuring that industries report their emissions and for the authorities to monitor compliance.

An ambient air quality management system consists of various hardware, software and communication systems as well as activities related to the ongoing maintenance and calibration of the system. Continuous ambient air quality monitoring requires, among other things, a set of trace gas analysers housed in a secure shelter, meteorological equipment and a data communication and acquisition system, as well as various other mechanical, civil and electrical structures such as an inlet manifold, fencing, a concrete plinth, an air conditioner, an Uninterrupted Power Supply (UPS) and safety devices such as a lightning conductor. As part of a monitoring network design (macro- and micro-siting) it is important to consider:

- the proximity of residential areas,
- the location of industries, major roads, sources of domestic fuel burning emissions etc.,
- the dominant wind direction,
- dispersion modelling results,
- topography,
- the location of existing monitoring stations,
- sensitive environments,
- sensitive populations, and
- trans-boundary transport of air pollution from neighbouring sources.

(a) Continuous Ambient Air Quality Monitoring

Continuous ambient air quality monitoring ensures that the environment is being properly protected and helps Local Government manage the impact of atmospheric emissions on the environment. This type of monitoring provides continuous, accurate data on pollution concentrations at a specific location. However, limitations of this type of monitoring are associated with spatial coverage, technical skills required for maintenance and calibration as well as the ongoing financial implications. No air monitoring stations are operated within the Chris Hani DM.

Figure 42: Examples of continuous ambient air quality monitoring stations

At the 11th Annual Air Quality Lekgotla, held on 3-5 October 2016 in Mbombela, the DEA presented the proposed monitoring categories as part of the draft National Ambient Air Quality Monitoring Strategy. The Chris Hani DM will be categorized as level two when the strategy is published. Level two requires installations of continuous monitoring to be informed by screening and monitoring to include PM, SO_2 and O_3 (DEA, 2016). Monitoring of other specific pollutants can be considered.

(b) Passive Diffusive Monitoring

Passive monitoring is an inexpensive method of monitoring over a large area and requires little human intervention. Passive badges can measure a range of pollutants including SO_2, NO_2, O_3, hydrogen sulphide (H_2S), hydrochloric acid, VOCs, and various aldehydes among others. Passive diffusive sampling calculates an average reading over a time period as opposed to real-time data acquisition that continuous monitoring can provide. Passive badges (Figure 43) have to be sent away to an accredited laboratory for analysis further extending the lag time in getting results (2 – 3 weeks). Passive sampling conforms to international methodologies and standards and can be used to validate dispersion modelling results.

However, there are limitations associated with passive monitoring. These include questionable concentrations, given that passive badge monitoring is based on diffusion of pollutants, making comparison with ambient air quality guidelines/standards difficult. Extreme meteorological conditions such as high humidity and temperatures influence diffusion rates, and hence, affect concentrations.

Figure 43: Passive badge sampling equipment

(c) Proposed Air Quality Monitoring for the Chris Hani DM

Screening should be performed within Chris Hani DM in order to identify areas where continuous monitoring is required. When the National Ambient Air Quality Monitoring Strategy is published, the Municipality should improve its monitoring network to comply with the strategy. The Chris Hani DM should support any provincial or District air quality monitoring initiatives. An effort should be made to ensure that all data and reports from Government and privately-owned stations are published on SAAQIS. To this end, agreements should be drawn up with privately owned stations.

6.3. Human Resources

As per Schedule 4, Part B, Section 156 of the Constitution, air pollution is an exclusive function of Local Municipalities (South Africa, 1996). Air quality functions are, therefore, primarily the responsibility of the Local Government, with support to be provided from Provincial and National Government. Within Chris Hani DM, support is provided to Local Municipalities by the District Municipality and Eastern Cape Province.

For the Chris Hani DM AQMP to be effective, co-operative governance and political buy-in across all spheres of government will be required, as well as the capacity to enforce compliance with new legislation. It is recognised that air quality management and control is primarily a function of District Municipalities with emission licensing functions undertaken by the Chris Hani DM in conjunction with the DEDEAT. In order to increase capacity in Local Government, authorities need to invest both time and capital. For Municipalities to fulfil their regulatory role in terms of air quality, dedicated Air Quality Officers and personnel need to be appointed. All newly appointed Air Quality Officers should be sent to undergo relevant training.

Municipalities are also required to undertake monitoring, data analysis and reporting on ambient air quality as per their mandate as air quality authorities. Training on calibration and maintenance of analysers in the ambient monitoring stations will be required, as well as training on data acquisition and analysis. For this task, technical personnel will need to be appointed. Alternatively, this function needs to be outsourced.

According to legislation (Act No. 39, 2005), Municipalities are required to appoint an Air Quality Officer. Currently, no dedicated Air Quality Officers have been appointed within Chris Hani DM, with air quality functions forming part of Environmental Control Officers' responsibilities. The Chris Hani DM currently has two ECOs who are assigned to air quality along with their other environmental and pollution control duties.

The Chris Hani DM should collaborate with Industry and other Municipalities which are actively involved in air quality matters. Inter-governmental co-operation and co-ordination will support information sharing and dissemination.

A summary of the air quality responsibilities of the Chris Hani DM as per the National requirements are given in Table 38.

Table 38: Air quality responsibilities of the Local Municipalities as per the National Requirements (NEM:AQA, 2004)

Air Quality Functions	National Requirements	Current Resources	Required Resources
Identify priority pollutants	Municipalities may, by utilizing a by-law, identify substances or mixtures of substances which represent a threat to health, well-being or the environment in the Municipality. As per the generic air pollution control by-law, a municipality must compile a list of substances (using set criteria) which must be submitted to Standards South Africa to develop local emission standards.	Eight National criteria pollutants have been identified (SO_2, NO_2, O_3, CO, Pb, PM_{10}, $PM_{2.5}$ and C_6H_6). No clear capacity exists for the identification and prioritisation of pollutants in the Municipality.	Measures are currently not required for identification of any additional priority pollutants in the Municipality.
Establish local emission standards	Municipalities may, by utilizing a by-law, establish local standards from point, non-point and mobile sources. If National or Provincial standards have been established, a municipality may not alter such standards except by establishing stricter standards. As per the generic air pollution control by-law, a municipality must formally request Standards South Africa to develop local emission standards. Standards South Africa will then develop (using a set methodology) local emission standards. Once developed, the local emission standards will be published.	National emission standards were established as part of the Listed Activities and Minimum Emissions Standards legislation. Insufficient capacity exists for the drafting of local emission standards.	More stringent local emission standards are currently not required for pollution sources in the Municipality.
Establish local air quality standards.	No provision is made for the setting of standards by local authorities. However, Local Government may establish more stringent local air quality guidelines for air quality management.	National Air Quality Standards have been established by DEAT. Local air quality guidelines have not been established for the Municipality.	The National Air Quality Standards should be adopted for the Municipality. More stringent local air quality guidelines are not required.

Appoint Air Quality Officers.	Each municipality must designate an Air Quality Officer from its administration to be responsible for air quality management. Duties and functions of an Air Quality Officer have been prescribed in the generic air pollution control by-law.	No dedicated Air Quality Officers have been appointed within Chris Hani DM. Air quality functions currently form part of other Environmental Control Officers' responsibilities and are not separate, dedicated positions.	A dedicated Air Quality Officer should be appointed in Chris Hani DM. Air Quality Officers should attend air quality courses including monitoring, modelling and management courses.
Develop and implement an Air Quality Management Plan.	Each municipality must include an Air Quality Management Plan in its Integrated Development Plan. An annual report must be submitted on the implementation of its Air Quality Management Plan.	Limited capacity is available to develop and implement an Air Quality Management Plan.	An AQMP Implementation Task Team should be established in the Municipality comprising representatives from industry, Government, NGOs, CBOs and other institutions. The Implementation Task Team should meet on a quarterly basis during the implementation phase. The Implementation Task Team should submit an annual report on the implementation of the AQMP.
Ambient air quality monitoring.	The National Framework has established national norms and standards for municipalities to monitor ambient air quality.	No continuous ambient air quality monitoring stations are currently being operated in Chris Hani DM.	Chris Hani DM should provide support when monitoring by the Province, District, Industry and Academia is conducted.

6.4. Vision, Mission and Objectives

The vision, mission, goals and objectives developed for the Chris Hani DM reflect the vision, mission and general approach for air quality management at the National, Provincial and Local levels. The National Framework for Air Quality Management (Government Notice No. 919, 2013). was referenced during this process to ensure the Municipality is in line with National requirements.

6.4.1. Vision

Attainment and maintenance of good air quality for the benefit of all inhabitants and natural environmental ecosystems within the Chris Hani DM.

6.4.2. Mission

- To ensure the maintenance of good air quality through proactive and effective management principles that take into account the need for sustainable development into the future.
- To work in partnership with communities and stakeholders to ensure that the air is healthy to breathe and is not detrimental to the well-being of persons in the Chris Hani DM.
- To ensure that future developments (transportation, housing etc.) minimise air quality impacts.
- To reduce the potential for damage to sensitive natural environmental systems from air pollution both in the short and long term.
- To facilitate intergovernmental communication at the Local, Provincial and National levels to ensure effective air quality management and control in the Chris Hani DM.

6.4.3. Commitment

- Integrating air quality considerations into the town planning mechanisms especially when considering housing, transportation and spatial planning developments.
- Raising awareness around air quality issues, thereby promoting community well-being and empowerment.

6.4.4. Strategic Goals and Objectives

- Implementing the Air Quality Management Plan within the Chris Hani DM.
- Assigning clear responsibilities and functions for air quality management.
- Air quality training of current and future air quality personnel at Local Level.
- Obtaining the necessary resources and funding for air quality management.

- Maintaining good air quality within the boundaries, with specific emphasis on PM_{10}, $PM_{2.5}$, NO_x and SO_2 concentrations.
- Compliance monitoring and enforcement of air quality legislation, policies and regulations.
- Assessing the contribution of various activities / sources to ambient air quality and establishing measures to control emissions from these sources.

7. EMISSION REDUCTION AND MANAGEMENT INTERVENTIONS

Proposed emission reduction measures for sources identified in the Chris Hani DM are presented in this section. Where possible, timeframes were assigned to each intervention. Generic timeframes ranging from short term (1 – 2 years), medium term (3 – 5 years) and long term (5 – 10 years) were assigned.

Where possible, emissions from industrial activities as well as other contributing sectors were quantified as part of the Baseline Assessment (Section 5). Chris Hani DM should formally request emissions information from those industries that had not provided such information at the time of this report. In addition, smaller companies and industries that were not included in this plan should be identified and quantified.

7.1. Industries

Industries include Listed activities and Small Boilers. The scale of the intervention and the subsequent implementation strategy should be tailored to the size of the industry.

7.1.1. Proposed Interventions

The inventory compiled for the Chris Hani DM as part of the AQMP represents the first step towards identifying and quantifying industrial emissions. The Chris Hani DM will need to update this emissions inventory to include the other industries where no information was available.

At a minimum, the emissions inventory should include information on

- company name and contact details,
- type of fuel burning appliance (e.g. boiler, incinerator, furnace),
- make and model of fuel burning appliance,
- type of fuel,
- quantity of fuel used,
- stack parameters (height, diameter, gas exit temperature and gas exit velocity),
- sulphur and ash content of fuel (where applicable),
- periods of operation, and
- control equipment (e.g. grit collectors).

Proposed interventions that the Municipality should enact in order to manage emissions from industrial sources are given in Table 39.

Table 39: Proposed emission reduction interventions for industries and controlled emitters

Intervention	Responsible Party	Timeframe
Develop and regularly update an electronic database of all Listed Activities operating within Chris Hani DM. Include all information regarding Listed Activities in the NAEIS.	DM, DEDEAT	Short Term / Ongoing
Identify any Listed Activities currently operating without emissions licences.	DM, DEDEAT	Short Term / Ongoing
Support DEDEAT in conducting compliance monitoring of AEL conditions.	DM, DEDEAT, DEA	Ongoing
Discuss emission reduction measures with individual companies that operate within DM.	DM, DEDEAT	Medium Term
Implement short term emission reduction measures.	DM, DEDEAT	Medium Term
Mid-term review of reduction measures.	DM, DEDEAT	Medium Term
Identify and register all controlled emitters. Record information received in an electronic database.	LM, DM, DEDEAT	Medium Term / Ongoing
Develop emission reduction plan/measures for controlled emitters.	LM, DM, DEDEAT	Medium Term
Enforce air emissions reduction measures for controlled emitters.	LM, DM, DEDEAT	Medium to Long Term
Conduct monitoring and random inspections in order to evaluate industry and controlled emitter's compliance to the standards.	LM, DM, DEDEAT	Ongoing
Identify non-listed sources of air pollution in the province.	LM, DM, DEDEAT	Medium Term
Conduct compliance monitoring of non-Listed Activities (get reports from activities).	LM, DM, DEDEAT	Medium Term
Develop emission reduction measures for identified activities.	LM, DM, DEDEAT	Medium Term
Identify priority pollutants per LM.	LM, DM, DEDEAT	Medium Term

At the 5th Annual Air Quality Governance Lekgotla a resolution was undertaken to provide a document to ensure consistent implementation of the Listed Activity regulations (DEA, 2012). Contained in the draft version of this document are mitigation methods applicable to each type of Listed Activity. An overview of these recommended interventions given in the table below (Table 40).

Table 40: Interventions for Listed Activities (DEA, 2012)

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
Additives can be mixed into the fuel to reduce emissions (for example, lime can reduce SO_2 emissions from combustion of solid fuels)	✓									
Using coal with lower sulphur content can reduce sulphur dioxide emissions					✓					
Fugitive emissions from materials receiving, handling and pre-processing can be reduced by:										
○ Water/suppressant spraying/misting at points of transfer and on stockpiles (however, in the case of solid biomass combustion installations this may result in odorous emissions) (solid fuel/material)	✓			✓	✓					
○ Enclose the area in which materials receiving, handling, pre-processing and/or storage occurs and use suction send air to particulate abatement equipment (solid fuel/material)	✓			✓	✓					
○ Placing suction hoods at transfer points which lead to particulate abatement equipment (solid fuel/material)	✓			✓	✓					
○ Ensuring adequate seals are in place (liquid/gas fuel/material)	✓									

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
○ Using vapor return systems where appropriate (liquid/gas fuel/material)	✓									
○ Trucks/wagons should be covered with tarpaulins when in transit					✓					
○ Unpaved surfaces should be wetted, paved or have binders applied to them					✓					
Flue gases can be cleaned using:										
○ Scrubbers to reduce PM, SO_2 and NO_x (also HF, VOCs, CH_5N, CH_2CHCN, Cl_2, NH_3, HCN, H_2S, Fluorides, HCl, gaseous metals, NH_4, CO, CO_2, PCDD/CPDF and SO_3 where applicable) emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	
○ Cyclones to reduce PM (and particulate metals where applicable) emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	
○ Baghouses to reduce PM (and particulate metals where applicable) emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	
○ Electrostatic precipitators to reduce PM (and particulate metals where applicable) emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	
○ Flue gas desulphurization to reduce SO_2 emissions	✓			✓	✓					
○ Selective/non-selective catalytic reduction to reduce NO_x emissions	✓			✓	✓					

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
○ Flue gas must be rapidly cooled to below 200ºc to avoid formation of Dioxins, Furans and other POPs					✓					
PM should be collected and returned to the material stream by abatement equipment				✓	✓					
Waste materials (for example ash and recovered PM) should be handled correctly, and the disposal area managed properly	✓	✓	✓			✓				
Drying of solid biomass (using steam from the combustion plant, waste heat from the combustion exhaust gases or electrical heating) before combustion can reduce particulate emissions	✓									
Emission of VOCs should be reduced by flaring, absorption, adsorption scrubbers and/or captured, condensed and returned to bulk storage		✓	✓		✓	✓		✓		
A leak detection and repair program approved by the licensing authority should be instituted		✓				✓				
Sleeves must be fitted to roof legs, slotted pipes and/or the dipping well on floating roof tanks to minimize emissions		✓				✓				
Periodic tests should be done on relief valves on pressurized storage		✓				✓				
Vapour recovery units must be fitted to installations with a throughput of 5 000m^3 per annum or higher (liquid/gas fuel/material)		✓								

Intervention	Combustion Installations	Petroleum Industry, the Production of Gaseous and Liquid Fuels as well as Petrochemicals from Crude Oil, Coal, Gas or Biomass	Carbonization and Coal Gasification	Metallurgical Industry	Mineral Processing, Storage and Handling	Organic Chemicals Industry	Inorganic Chemicals Industry	Thermal Treatment of Hazardous and General Waste	Pulp and Paper Manufacturing Activities, including By-Products Recovery	Animal Matter Processing
Vapours from the distillation and pyrolysis processes should be treated by scrubbers		✓								
Coke oven gas can be recovered for reuse as an energy source and/or to produce by-products			✓							
Off-gases should be cleaned by cooling/condensing (to remove drop out H_2O, tar and organics with low boiling points) and/or scrubbers (to remove PM, SO_2, H_2S and NO_X)			✓							
During the coal gasification process, use of a lock chamber which removes gas from the chamber and sends it to the gasifier or syngas stream before the chamber is opened to take in a new batch of coal will reduce the release of gaseous and particulate matter emissions			✓							
Emissions from the sinter strand should be collected by a wind box and sent to abatement				✓						
PM should be removed from air in the cooling circuit before it is released				✓						
Fumes and vapours emitted during production processes should be captured by extraction hoods over the areas in which they are emitted and abated by scrubbers, cyclones and electrostatic precipitators				✓						
Odorous compounds should be abated through combustion or adsorption using scrubbers										✓

7.2. Transportation

7.2.1. National Government Interventions

In 2017, the Department of Transport (DoT) published the Draft Green Transport Strategy: 2017-2050. As the road transport sub-sector contributes 91.2% of the sector's total emissions, mitigation of this sub-sector offers the highest potential benefits. As such, suggested strategies include integrating rail, taxi and bus services; a taxi recapitalization programme which aims replace old, unsafe taxis with newer, more efficient vehicles; promoting cleaner fuels for the taxi industry (an efficient mitigation strategy as approximately 67% of the South African population uses mini-bus taxis); construction of low-carbon, climate resilient road infrastructure including bus lanes, railways and non-motorised transport (e.g. cycling or walking) infrastructure; and incentivize the uptake of sustainable transport modes. Rail transportation infrastructure needs to be improved so as to handle freight transport and hence reduce road transport. (Government Notice No. 886, 2017).

The Air Quality Act makes provision for the Minister or Provincial MECs to declare vehicles or vehicles falling within a specified category as a 'controlled emitter'. Emission standards, which include standards setting the permissible amount, volume, emission rate or concentration of a specified substance or a mixture of substances, need to be established for such emitters. Measurements of emissions from controlled emitters must also be carried out. The Act also makes provision for the declaration of a substance or a mixture of substances as a 'controlled fuel'. Standards may be established for the use, manufacture, sale and composition of the controlled fuel. Alternatively, the manufacture, sale or use of the controlled fuel could be prohibited (Government Notice No. 919, 2013).

7.2.2. Proposed Interventions

Vehicle emissions within the Chris Hani DM are not considered to be a major source of atmospheric emissions. Vehicle numbers are significantly lower than those observed within major cities such as Johannesburg and Cape Town.

Proposed emission reduction interventions to address emissions from the transportation sector are given in Table 41.

Table 41: Proposed emission reduction interventions for transportation

Intervention	Responsible Party	Timeframe
Update the vehicle emissions database with the latest traffic count data as it becomes available.	LM, DM	Short Term / Ongoing
Compile a detailed assessment of the vehicle fleet in the Municipality including information on vehicle numbers, type, age and fuel usage.	LM, DM	Medium Term
Synchronise traffic lights.	LM, DM	Ongoing
Create inventories for vehicular emissions.	LM, DM	Medium Term
Construct public transport infrastructure	LM, DM	Long Term
Encourage the use of public transport through information campaigns	LM, DM	Short Term/ Ongoing

7.3. Domestic Fuel Burning

7.3.1. National Government Interventions

The DoE published the Draft Post-2015 National Energy Efficiency Strategy in 2016. This strategy aims to make energy affordable to everyone and to minimise the effects of energy usage on human health and the environment. Measures to reduce energy demand include the successive tightening of building standards while the feasibility of energy performance certificates is investigated; the successive tightening of minimum energy performance standards for household appliances; continued energy labelling of appliances and potentially introducing an energy endorsement label for the most efficient appliances in each class; the investigation of a scrappage scheme for older, less efficient appliances; and awareness campaigns around the cost-benefits of energy efficiency within households. The approach is focused on energy efficiency in higher income areas as well as in state-subsidised housing which will incorporate energy efficiency measures (Government Notice No. 948, 2016).

Residential air pollution is usually associated with low income settlements. In response to this problem, the DEA published the Draft Strategy to Address Air Pollution in Dense Low-Income Settlements. Objectives of this strategy include ensuring air pollution reduction efforts made by different parties (government departments, Provinces, Municipalities, parastatals, community based organisations, private companies and academic and research institutions) are coordinated; facilitating the implementation of emission reduction interventions in low-income settlements; and ensuring continued monitoring, evaluation and reporting on the successes and failures of the proposed interventions and on air quality improvements. In order to achieve these objectives, measures that should be implemented include the establishment of The National Coordinating Committee (NCC) on Residential Air Pollution; the effective prioritization of air pollution interventions in dense, low-income settlements; the provision of affordable or subsidised clean energy alternatives; ensuring that low-income houses are built in line with energy efficiency housing guidelines; influencing development planning initiatives to take into account air quality issues; encouraging social upliftment programs with air quality benefits; the creation of public awareness of air pollution through campaigns and information materials; and annual reports on the implementation of interventions. (Government Notice No. 356, 2016).

The top-down ignition method, called 'Basa Njengo Magogo', which has proven to be successful, is considered a short- to medium-term solution to address domestic fuel burning (Figure 44). This method, meaning 'make fire like grandmother', is a top-down approach to fuel loading in mbawulas and stoves. In the classical bottom-up fire ignition approach, the order of preparing a fire is a few lumps of coal, followed by paper, wood kindling and ignition. The bulk of the coal is then added once the fire is established. In the 'Basa Njengo Magogo' method, the order of preparing a fire is coal, paper, wood followed by ignition and a few pieces of coal at the top (Makonese, Masekameni, Annegarn, & Forbes, 2015). Smoke generated in the latter method is burnt as it rises through the hot zone, resulting in reduced smoke emissions. The Basa Njengo Magogo method reduces PM_{10} and $PM_{2.5}$ emissions by 76% to 80% (Makonese, Masekameni, Annegarn, & Forbes, 2015).

Figure 44: The 'Basa Njengo Magogo' fire-lighting Method (left) and classical fire lighting method (right)

In addition to the method of ignition, ventilation rates affect the emissions from domestic fuel burning. High stove ventilation rates result in 50% lower PM_{10} and $PM_{2.5}$ emissions than low ventilation rates (Makonese, Masekameni, Annegarn, & Forbes, 2015). Ventilation rates can be influenced by the number and size of the holes made in rural stoves (Figure 45).

Figure 45: a) high ventilation brazier, b) medium ventilation brazier, and c) low ventilation brazier

7.3.2. Proposed Interventions

Emissions from domestic fuel burning need to be accurately determined to ensure that the contribution to the overall ambient air quality in the Chris Hani DM is accurately quantified. As part of the Status Quo Assessment (Section 5), a first step in the quantification of domestic fuel burning was undertaken. This initial domestic fuel burning emissions inventory needs to be updated as population statistics become available.

An awareness campaign should be initiated in the Chris Hani DM to educate people on the social and financial benefits of using alternative options. This awareness campaign (or strategy) should use all forms of media including television, radio, newspapers and flyers. The use of other forms of domestic energy such as low smoke fuels (such as char briquettes), gas (Liquid Petroleum Gas) and paraffin should also be encouraged (where available and accessible).

The introduction of energy efficiency measures into low-cost housing is considered to be a viable option. Such measures include solar water heaters, roof insulation and energy efficient lighting to reduce financial costs and environmental impacts.

Although electrification is often the preferred option, domestic fuels are often still used even after electrification due to factors such as affordability, accessibility and social preferences.

In 2013, Eskom initiated a pre-feasibility study for an offset project, whereby the stack emissions from Eskom's power plants would be offset by household emission reductions. This intervention project can be implemented in areas where air quality is impacted both by Eskom and domestic fuel burning in households. Interventions will include

- fully retrofitting subsidy houses with thermal insulation in both the walls and ceilings,
- installing ceilings and ceiling insulation in houses that do not have ceilings,
- designing and constructing new subsidy houses which have a high thermal standard (shell insulation, ventilation, orientation, surface to volume ratio and solar heat absorption),
- replacing old stoves with new smokeless stoves,
- subsidising electricity and electric heaters, and
- providing subsidised Liquefied Petroleum Gas (LPG) and heating appliances (and possibly also cooking appliances) through a "stove-for-LPG" exchange programme.

It is proposed that a similar offsetting project should be considered within the Chris Hani DM in areas with high domestic fuel burning emissions.

An overview of the proposed emission reduction interventions for domestic fuel burning are listed below (Table 42).

Table 42: Proposed emission reduction interventions for domestic fuel burning

Intervention	Responsible Party	Timeframe
Update the domestic fuel burning emissions inventory as population statistics become available.	DM	Medium Term
Conduct a count of all illegal settlements and establish an estimate of the number of residents within these settlements.	LM, DM	Medium to Long Term
Identify and prioritise the residential areas using fossil fuels that require installation of air quality monitoring equipment.	LM, DM	Medium Term
Develop a domestic fuel burning strategy.	LM, DM, DEDEAT	Medium Term
Create awareness campaigns around the negative health impacts of domestic fuel burning.	DM, DEDEAT, DEA	Short Term
Continue encouraging the implementation of the 'Basa Njengo Magogo' method in informal settlements.	LM, DM	Short Term
Encourage the distribution of alternative forms of domestic energy such as LPG, LSF, gas, methanol, etc.	DM, DEDEAT	Medium Term
Implement electrification in informal settlements.	LM, DM	Medium to Long Term
Ensure that all low-income formal houses have insulated ceilings.	LM, DM	Short to Medium Term

7.4. Biomass Burning

7.4.1. Proposed Interventions

Emissions arising from biomass burning are difficult to accurately quantify due to the seasonal and irregular nature of this source.

Public awareness should be raised about the dangers associated with uncontrolled fires and the implications for air quality and human health. Possible forms of media for this campaign include community forums, television, radio, newspapers and posters. Establishing relationships between systems operators (e.g. the CSIR, ARC, etc.) to help identify, manage, and quantify the emissions from biomass burning.

The proposed emission reduction interventions for biomass burning are given in Table 43.

Table 43: Proposed emission reduction interventions for biomass burning

Intervention	Responsible Party	Timeframe
Plan and develop fire early warning systems	LM, DM	Short Term
Plan and provide for a buffer zone between residential and vegetation areas	LM, DM	Short Term
Plan and provide fire breaks in high risk vegetation areas	LM, DM	Ongoing
Ensure compliance with fire regulations and by-laws	LM, DM	Ongoing
Identify and quantify emissions from biomass burning.	LM, DM	Short to Medium Term and Ongoing
Identify the role of fire services to assist in air pollution control.	LM, DM	Short Term
Each local Fire Department should maintain and update a database of the locations of veld fires and the extent of the areas burnt.	LM, DM	Short to Medium Term (initiation) and Ongoing
Establish a biomass burning advisory line which will help people to burn firebreaks on days that are not hazardous to air quality and when weather conditions are not likely runaway fires.	LM, DM	Medium Term
A complaints line should be set up for reports regarding negligent fire starters	LM, DM	Short Term
Update biomass burning inventories.	LM, DM	Medium Term

7.5. Agriculture

7.5.1. Proposed Interventions

Agriculture is a dominant land use within many areas of Chris Hani DM. Emissions from agricultural activities such as crop spraying, crop burning, harvesting and N-fertilizer application are potentially significant sources of air pollution in the Municipality.

Adjusting the methods for managing land and growing crops can result in the reduction of agricultural emissions. Changing from the use of chemical fertilizers to manure can reduce N_2O emissions by 3% and CO_2 emissions by 36% (Ren, et al., 2017). Though this change increases CH_4 emissions from fertilized fields by 84% (Ren, et al., 2017), it should be noted that CH_4 emissions from manure occurs naturally in fields where animals graze. Sidedressing fertilizer after the crop's root systems have developed enough to support rapid nitrate uptake rather than broadcasting fertilizer at planting can reduce N_2O emissions further (Sadeghpour, Lefever, Ketterings, & Czymmek, 2016). In addition to these measures, overfertilization should be avoided (Sadeghpour, Lefever, Ketterings, & Czymmek, 2016).

Information on the quantity of pesticides sold in the Municipality should be obtained as a first step in quantifying the potential impact of crop spraying. It is estimated that less than 0.1% of sprayed pesticide reaches the target pest; the remainder enters the environment and can impact other species of animals as well as human beings (Goldblatt, 2017). According to the World Bank Group, where possible, biological pest and disease control methods should be used instead of chemical pesticides. If chemical pesticides are required, preference should be given to selective pesticides with low environmental impact quotients as opposed to broad spectrum pesticides that have a greater impact on non-target species. Low-drift nozzles, using the largest droplet size and lowest pressure that are suitable for the product can reduce pesticide drift. Buffer zones should be established around watercourses, residential and built-up neighbourhoods as well as livestock and food storage areas. Impacts associated with crop spraying can be minimised by ensuring that crops are sprayed during periods of favourable meteorological conditions, such as when wind speeds are low and the weather is dry, to reduce spray drift (World Bank Group, 2016).

Proposed emission reduction interventions for agricultural activities are given in Table 44.

Table 44: Proposed emission reduction interventions for agriculture.

Intervention	Responsible Party	Timeframe
Obtain information on the quantity of pesticides and fertilizers consumed in the LM. Develop relationships with pest control associations in the area.	LM, DM	Ongoing
Ensure farmers use best farming practices regarding fertilizer and pesticide use through information campaigns.	LM, DM, DEDEAT, DEA	Ongoing
Adopt environmentally sound pest control techniques.	LM, DM	Ongoing
Ensure that crop spraying takes place under favourable atmospheric conditions that reduce	LM, DM	Ongoing

spray drift, i.e. when wind speeds and humidity levels are low.		
Allow agricultural burning only under favourable dispersion conditions which occur in the middle of the day.	LM, DM	Ongoing
Update the agricultural emission inventories.	LM, DM	Medium Term

7.6. Mining Operations

7.6.1. Proposed Interventions

Possible emission reduction interventions that can be employed by mining companies within the Chris Hani DM include

- wet suppression or chemical surface treatment of unpaved haul roads as well as sweeping, vacuum sweeping, or watering of paved haul roads which reduces dust emissions significantly (Olsen, 2015)
- replacement of haul trucks, as far as possible, with conveyor belts can further reduce dust emissions from transportation of products especially in conjunction with wetting of the product during transport and at transfer points as well as belt cleaning (Colinet, Rider, Listak, Organiscak, & Wolfe, 2010),
- dust emissions from screening of coal can be controlled by wet suppression (US EPA, 1995),
- cyclones can be used to control dust emissions from secondary and tertiary crushing of coal (US EPA, 2003),
- either topical spray consisting of magnesium chloride, other salt solutions, vinyl copolymer or hay crimping can be used to reduce fugitive dust emissions from tailing dam walls (Degner, Horn, Galligan, Bernard, & Jameson, 2017),
- recovering methane from coal mines simultaneously during the mining of coal, from ventilation air or after an underground mine has been abandoned for utilization as an energy source can reduce methane emissions (Singh & Kumar, 2016),
- planned vehicle maintenance programmes to reduce CO_x emissions (Dietz, Gardner, Gilligan, Stern, & Van den Bergh, 2009), and
- development of a monitoring system for emissions released during blasting and other activities.

The emission reduction interventions proposed for mining are given in Table 45.

Table 45: Proposed interventions for mining in Chris Hani DM

Intervention	Responsible Party	Timeframe
Develop a list of active mines and mining operations in the Chris Hani DM, with associated emissions inventories.	LM, DM	Ongoing
Monitor fugitive emissions from mining activities in the Municipality. Any exceedances of air quality standards should be investigated and dealt with appropriately.	LM, DM, DEA	Medium Term / Ongoing

7.7. Waste Treatment and Disposal

7.7.1. Proposed Interventions

Waste treatment and disposal facilities need to be carefully maintained as emissions increase significantly when equipment deteriorates.

Landfill sites within the Chris Hani DM need to be issued with permits to ensure that these landfills are effectively managed and controlled. The responsibility of issuing landfill permits and of ensuring that landfills operate within their permits lies with the Province. Up to 57% reduction in methane emissions can be achieved by reducing waste disposal, the separate collection of biodegradable waste, the use of landfill gas for generating power and flaring of landfill gas (Boerboom, Vatamanu, & Zegers, 2010). Since 2016, several Municipalities within South Africa, including the eThekwini Municipality, City of Cape Town and Drakenstein Municipalities, have initiated waste-to-energy programmes.

Awareness campaigns around the environmental benefits of recycling should be promoted. These campaigns should focus on schools with recycling bins and depots installed at each school in the region. Proper refuse collection in all areas within the Chris Hani DM will also minimise illegal waste dumping and domestic waste burning in informal settlements.

Wastewater treatment works emit greenhouse gases such as carbon dioxide, methane and nitrous oxide. WWTW need to be maintained in order to keep methane emissions to a minimum (Global Methane Initiative, 2013). According to the Global Methane Initiative (2013), any methane gas produced should be collected and used to generate electricity to power the WWTW or purified to pipe-line quality and sold. This reduces CH_4 emissions from WWTW while reducing the Municipality's reliance on fossil fuels for electricity. Operating biological wastewater treatment plants at high solid retention times can reduce N_2O emissions by maintaining low ammonia and nitrate concentrations (Campos, et al., 2016). Capturing and treating greenhouse gas emissions from WWTW will reduce the amount of emissions released, however capital costs to introduce the technology required will be high (Campos, et al., 2016).

The proposed interventions for waste treatment and disposal are provided in Table 46.

Table 46: Proposed emission reduction interventions for waste treatment and disposal

Intervention	Responsible Party	Timeframe
Ensure all operating incinerators are issued with permits and are operating within their permit requirements.	LM, DM	Short Term
Maintain a current database of landfill sites, including those with permits and those without.	LM, DM, DEA	Ongoing
Introduce awareness programmes and public education of waste minimization and recycling initiatives.	LM, DM	Medium Term
Establish recycling bins at schools in the Municipality.	LM, DM	Medium Term
Reduce illegal dumping and the creation of informal landfills through efficient waste removal service delivery in residential areas.	LM, DM	Medium Term
Undertake landfill gas monitoring and management schemes.	LM, DM	Ongoing
Initiate a waste-to-energy project to reduce waste at landfill sites and produce energy.	LM, DM	Long Term
Initiate waste to energy mechanisms in WWTW.	LM, DM	Long Term

8. RECOMMENDATIONS AND CONCLUSION

8.1. Pollutants, Sources and Impact Areas

The main pollutants identified to be of concern in the Chris Hani DM are CO, PM_{10}, $PM_{2.5}$ and NO_X. The main sources influencing the air quality in the Chris Hani DM have been identified to be:

- Mining – sand and coal mining is the largest source of PM_{10} emissions in the Chris Hani DM. Main sources of PM include the use of vehicles on unpaved and paved roads for transporting ore, personnel, waste rock, etc.; blasting; overburden stripping; ore and overburden handling; crushing and screening of ore; and wind entrainment from stockpiles.
- Transportation – vehicles are the second largest source of NO_X and CO within the Chris Hani DM. Data regarding vehicle count numbers and rail networks is required to improve emission estimates.
- Agricultural activities – agricultural activities are considered to be an important source of ambient particulate emissions with the third highest PM contribution in the Chris Hani DM.
- Biomass burning –biomass burning is the major contributor of CO (96.7%) and NO_X (54.6%) within the Municipality.
- Domestic fuel burning – emissions from coal, wood and paraffin burning in informal settlements include significant quantities of PM, SO_2, and NO_X. Health effects from these emissions can be greater than those from other sectors due to the proximity of the emission source to human habitations.
- Denuded land – denuded land contributes to particulate matter within Chris Hani DM.
- Wastewater treatment works – WWTW are the largest contributors of VOCs within Chris Hani DM. Waste gases from WWTW can be captured and used for electricity generation.
- Landfills – emissions include PM and methane. Methane from landfills can be captured and used for electricity generation.
- Small boilers – boilers contribute to SO_2, NO_X and PM emissions within Chris Hani DM.
- Industries – information regarding the Listed Activities in Chris Hani DM is limited. An investigation of Listed Activities conducted without a license is required to improve emission estimates.
- Other fugitive dust sources such as unpaved roads – emissions have not been quantified as part of the AQMP.

Mining was identified as the main source of particulate matter emissions (61.6%) followed by Biomass burning (23.6%) and agricultural activities (11%). Biomass burning was identified as the largest contributing source of NO_X and CO (54.6% and 96.7% respectively). By mass, biomass burning contributes the most criteria pollutants in Chris Hani DM (74.42%) followed by mining (16.2%) and vehicles (5.02%).

8.2. Capacity Building within Government

The current capacity for effective and co-ordinated air quality management of the Chris Hani DM is limited by the shortage of personnel, skills and tools. Air quality management is a relatively new function within the Municipality. Where required, air quality support is provided to Chris Hani DM by the Province.

8.2.1. Human Resources

It is recommended that an Air Quality Officer be appointed in Chris Hani DM. However, given the resources and finances required for this appointment, it is recommended that the current support provided to the Eastern Cape Province be continued and modified according to specific air quality management needs as they arise. Sufficient training of officials should be conducted with regards to the air quality management needs of the Municipality.

8.2.2. Air Quality Management Tools

Air quality management tools are required in the Chris Hani DM to effectively fulfil their air quality management functions. Such tools include emissions inventory software (Microsoft Excel will be sufficient), dispersion modelling software and air quality monitoring hardware. The first step in compiling an emissions inventory for the Chris Hani DM has been achieved as part of this AQMP. The Chris Hani DM should complete and regularly update the emissions inventory. As and when dispersion modelling skills are available, a range of models are available either as freeware or for purchase.

The Chris Hani DM should not currently acquire new Ambient Air Quality Monitoring Stations. A screening process should first be undertaken, as per the draft National Ambient Air Quality Monitoring Strategy, to establish whether there is a need for new Ambient Air Quality Monitoring Stations in the District.

8.2.3. Knowledge and Information Management

The actions that should be implemented by the Chris Hani DM include:

- Develop and implement an air quality management plan (AQMP) and ensure that it is included in the IDP.

- Continually review the AQMP and implement the required changes. After five years, a formal review of the AQMP, its implementation and any required changes should be undertaken and published.
- Develop and implement an awareness strategy for air quality in the municipality, including input from the Province and Local Municipalities within the District.
- Air quality officers (and ECOs tasked with air quality duties) should regularly attend training provided by the Province/District.
- Support the Province in identifying and recommending AQM courses to train officials.
- Expand the stakeholder database for non-industry emissions.
- Provide support to the Province with regards to updating NAEIS annually.
- Continually update the Chris Hani DM emission inventory.

8.3. Summary of Emission Management Interventions

Emission reduction interventions have been recommended for air pollution sources in the Chris Hani DM. Interventions for the major sources are summarised in the sections below. The proposed interventions should be tailored by the Chris Hani DM for each specific source.

8.3.1. Industries and Controlled Emitters

Recommended interventions for industries and small boilers:

- Develop and regularly update an electronic database of all Listed Activities operating within Chris Hani DM. Include all information regarding Listed Activities in the NAEIS.
- Identify any Listed Activities currently operating without emissions licences.
- Support DEDEAT in conducting compliance monitoring of AEL conditions.
- Discuss emission reduction measures with individual companies that operate within DM.
- Implement short term emission reduction measures.
- Mid-term review of reduction measures.
- Identify and register all controlled emitters. Record information received in an electronic database.
- Develop emission reduction plan/measures for controlled emitters.
- Enforce air emissions reduction measures for controlled emitters.
- Conduct monitoring and random inspections in order to evaluate industry and controlled emitter’s compliance to the standards.
- Identify non-listed sources of air pollution in the province.
- Conduct compliance monitoring of non-Listed Activities (get reports from activities).
- Develop emission reduction measures for identified activities.

- Identify priority pollutants per LM.

8.3.2. Transport

Recommended interventions for the transportation sector:

- Update the vehicle emissions database with the latest traffic count data as it becomes available.
- Compile a detailed assessment of the vehicle fleet in the Municipality including information on vehicle numbers, type, age and fuel usage.
- Synchronise traffic lights.
- Create inventories for vehicular emissions.
- Construct public transport infrastructure
- Encourage the use of public transport through information campaigns

8.3.3. Domestic Fuel Burning

Recommended interventions in the short to medium term for domestic fuel burning:

- Update the domestic fuel burning emissions inventory as population statistics become available.
- Conduct a count of all illegal settlements and establish an estimate of the number of residents within these settlements.
- Identify and prioritise the residential areas using fossil fuels that require installation of air quality monitoring equipment.
- Develop a domestic fuel burning strategy.
- Create awareness campaigns around the negative health impacts of domestic fuel burning.
- Continue encouraging the implementation of the 'Basa Njengo Magogo' method in informal settlements.
- Encourage the distribution of alternative forms of domestic energy such as LPG, LSF, gas, methanol, etc.
- Implement electrification in informal settlements.
- Ensure that all low-income formal houses have insulated ceilings.

8.3.4. Biomass Burning

Recommended interventions in the *short to medium term*:

- Plan and develop fire early warning systems
- Plan and provide for a buffer zone between residential and vegetation areas
- Plan and provide fire breaks in high risk vegetation areas

- Ensure compliance with fire regulations and by-laws
- Identify and quantify emissions from biomass burning.
- Identify the role of fire services to assist in air pollution control.
- Each local Fire Department should maintain and update a database of the locations of veld fires and the extent of the areas burnt.
- Establish a biomass burning advisory line which will help people to burn firebreaks on days that are not hazardous to air quality and when weather conditions are not likely runaway fires.
- A complaints line should be set up for reports regarding negligent fire starters
- Update biomass burning inventories.

8.3.5. Agriculture

Recommended interventions for agriculture:

- Obtain information on the quantity of pesticides and fertilizers consumed in the LM. Develop relationships with pest control associations in the area.
- Ensure farmers use best farming practices regarding fertilizer and pesticide use through information campaigns.
- Adopt environmentally sound pest control techniques.
- Ensure that crop spraying takes place under favourable atmospheric conditions that reduce spray drift, i.e. when wind speeds and humidity levels are low.
- Allow agricultural burning only under favourable dispersion conditions which occur in the middle of the day.
- Update the agricultural emission inventories.

8.3.6. Mining

Recommended interventions for mining:

- Develop a list of active mines and mining operations in the Chris Hani DM, with associated emissions inventories.
- Monitor fugitive emissions from mining activities in the Municipality. Any exceedances of air quality standards should be investigated and dealt with appropriately.

8.3.7. Waste Treatment and Disposal

Recommended interventions for waste treatment and disposal:

- Ensure all operating incinerators are issued with permits and are operating within their permit requirements.

- Maintain a current database of landfill sites, including those with permits and those without.
- Introduce awareness programmes and public education of waste minimization and recycling initiatives.
- Establish recycling bins at schools in the Municipality.
- Reduce illegal dumping and the creation of informal landfills through efficient waste removal service delivery in residential areas.
- Undertake landfill gas monitoring and management schemes.
- Initiate a waste-to-energy project to reduce waste at landfill sites and produce energy.
- Initiate waste to energy mechanisms in WWTW.

8.4. Human Resource Recommendations

Currently, the management of the Air Quality in Chris Hani DM forms part of the duties of ECOs. The Chris Hani DM the Eastern Cape Province should provide support to the ECOs until such time as a dedicated, full time AQO can be appointed.

The ECOs/AQO should advise the relevant department regarding the review of the AQMP, preferably every 5 years. In addition, the ECOs/AQO should advise the relevant department if they have identified any changes that should be made in the AQMP, prior to the scheduled review of the document. The AQMP should be considered to be a living document that will require changes as they arise.

The DEA published a Business Case Report (e-tool) in 2015 (DEA, 2015) that provides an assessment of functions and workloads that Air Quality Units / Divisions are required to undertake. It was developed to assist authorities in understanding capacity requirements for implementing the requirements of the NEM:AQA. The Business Case Report could be used as a reference source to identify the quality and number of human resources, the infrastructure and the financial resources required to effectively manage air quality within Chris Hani DM.

9. REFERENCES

Act No. 117. (1998). *Local Government: Municipal Structures Act, 1998*.

Act No. 2. (2000). *Promotion of Access to Information Act, 2000*.

Act No. 20. (2014). *National Environmental Management: Air Quality Amendment Act, 2014*.

Act No. 3. (2000). *Promotion of Administrative Justice Act, 2000*.

Act No. 32. (2000). *Local Government: Municipal Systems Act, 2000*.

Act No. 39. (2005). *National Environment Management: Air Quality Act, 2004*.

Act No. 45. (1965). *Atmospheric Pollution Prevention Act, 1965*.

Act No. 56. (2003). *Local Government: Municipal Finance Act, 2003*.

Act No. 61. (2004). *National Health Act, 2003*.

Andreae, M. O., & Merlet, P. (2001). Emission of trace gases and aerosols from biomass burning. *Global Biogeochemical Cycles, 15*(4), 955-966.

Atkinson, B. W. (1981). *Meso-Scale Atmosphere Circulations.* London: Academic Press.

Berg, C. N., Deichmann, U., Liu, Y., & Selod, H. (2016). Transport Policies and Development. *The Journal of Development Studies, 53*(4), 465-480.

Boerboom, R., Vatamanu, M., & Zegers, D. (2010). Dramatic reduction in emissions of methane from landfills in the Netherlands: additional measures considered. *Journal of Integrative Environmental Sciences, 7*(S1), 167-174.

Boschetti, L., Humber, M., Hoffmann, A. A., Roy, D., & Giglio, L. (2016). Collection 6 MODIS Burned Area Product User's Guide Version 1.0.

Burger, L. W., Stead, M., & Moldan, A. (2009). Prediction of motor vehicle air emission reductions through intervention policies. *National Association of Clean Air.*

Burger, R., Bhailall, S., & Van Basten, A. (2012). *Air Quality Impact Assessment Study: West Coast District Municipality Proposed Landfill, Western Cape Province.* Gondwana Environmental Solutions. Report Number RN_110070_MSA.

Campos, J., Valenzuela-Heredia, D., Pedrouso, A., Val del Río, A., Belmonte, M., & Mosquera-Corral, A. (2016). Greenhouse gases emissions from wastewater treatment plants: minimization, treatment and prevention. *Journal of Chemistry, 2016*.

CHDM. (2017). *Chris Hani District Municipality Integrated Development Plan 2017-2022.* Chris Hani District Municipality.

CHDM. (2018). *Draft By-Law Relating to Municipal Health Services.* Chris Hani District Municipality.

Colinet, J. F., Rider, J. P., Listak, J. M., Organiscak, J. A., & Wolfe, A. L. (2010). Best Practices for Dust Control in Coal Mining. *Information Circular 9517*. Pittsburgh: Department of Health and Human Services.

DAFF. (2018). *Eastern Cape Livestock Database.* Department of Agriculture, Forestry and Fisheries.

DEA. (2007). *Waste Disposal*. Retrieved 2018, from State of the Environment: http://soer.deat.gov.za/261.html

DEA. (2008). Clean Fires Campaign. Department of Environmental Affairs.

DEA. (2012). *Manual for Air Quality Management Planning.* Department of Environmental Affairs.

DEA. (2012). *S21 Companion Document.* Retrieved 2018, from South African Air Quality Information System: http://www.saaqis.org.za/Downloads.aspx?type=AQ

DEA. (2015). *2013/2014 Land-Cover Data Set*. Department of Environmental Affairs (These maps were developed using DEA GIS digital data, but these secondary products have not been verified by the DEA).

DEA. (2015). *Business Case Report: An Assessment of the Requirements for Municipalities and Provinces to Fully Undertake Air Quality Functions.* Pretoria: Department of Environmental Affairs.

DEA. (2016). National Ambient Monitoring Strategy. *11th Annual Air Quality Governance Lekgotla*. Department of Environmental Affairs.

DEA. (2018). *Air Quality Monitoring*. Retrieved 2018, from South African Air Quality Information System: http://www.saaqis.org.za/NAAQM.aspx

Degner, E., Horn, S., Galligan, Z., Bernard, R., & Jameson, J. (2017). *Tailings Dust Emissions, Chemical Engineering Undergraduate Thesis.* Fayetteville: University of Arkansas.

Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Van den Bergh, M. P. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *PNAS, 106*(44), 18452-18456.

DoE. (2018, January 9). *SA Fuel Sales Volume.* Retrieved January 29, 2018, from http://www.energy.gov.za/files/media/media_SAVolumes.html

DWA. (2013). *Green Drop Report: Municipal and Private Wastewater Systems, Final Draft.* Pretoria: Department of Water Affairs.

DWS. (2014). *Green Drop Progress Report.* Pretoria: Department of Water and Sanitation.

Elsom, D. (1996). *Smog Alert: Managing Urban Air Quality.* London: Earthscan Publications Ltd.

EMEP/EEA. (2013). *Air Pollutant Emission Inventory Guidbook.* Copenhagen: European Environment Agency.

EMEP/EEA. (2016). *Air Pollutant Emission Inventory Guidebook 2016.* Copenhagen: European Monitoring and Evaluation Programme/European Environment Agency. Retrieved from https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/11-natural-sources/11-c-other-natural-sources-pdf/view

EMEP/EEA. (2016). Air pollutant emission inventory guidebook 2016 - Emission factors. Retrieved 2018, from http://efdb.apps.eea.europa.eu

eNaTIS. (2013). *Vehicle Population Statistics for January/February 2013.* Retrieved 2018, from National Trafific Information System: http://www.enatis.com/index.php/statistics/13-live-vehicle-population?start=50

eNaTIS. (2018). *Vehicle Population Statistics for January/February 2018.* Retrieved 2018, from National Traffic Information System: http://www.enatis.com/index.php/statistics/13-live-vehicle-population

FAO. (2005). *Fertilizer use by crop in South Africa.* Rome: Food and Agriculture Organization of the United Nations.

Forsyth, G., Kruger, F., & Le Maitre, D. (2010). *National Veldfire Risk Assessment: Analysis of Exposure of Social, Economic and Environmental Assets to Veldfire Hazards in South Africa.* CSIR.

FSSA. (2004). *President's Report, FSSA Journal.* Pretoria: Fertilizer Society of South Africa.

Global Methane Initiative. (2013). *Municipal Wastewater Methane: Reducing Emissions, Advancing Recovery and Use Opportunities*.

Goldblatt, A. (2017). *Agriculture: Facts and Trends South Africa.* World Wildlife Fund.

Governmant Notice No. 579. (2010). Model air quality management by-law for easy adoption and adaptation by municipalities. *Government Gazette No. 33342*. Cape Town, South Africa: Government Printer.

Government Notice No. 602. (2015). Declaration of a small-scale char and small-scale charcoal plants as controlled emitters and establishment of emission standards. *Government Gazette No. 39220*. Cape Town, South Africa: Government Printer.

Government Notice No. 1138. (2007). The 2007 national framework for air quality management in the Republic of South Africa. *Government Gazette No. 30284*. Cape Town, South Africa: Government Printer.

Government Notice No. 1210. (2009). National ambient air quality standards. *Government Gazette No. 32816*. Cape Town, South Africa: Government Printer.

Government Notice No. 144. (2012). Highveld Priority Area air quality management plan. *Government Gazette No. 35072*. Cape Town, South Africa: Government Printer.

Government Notice No. 172. (2014). Declaration of greenhouse gases as priority air pollutants. *Government Gazette No. 37421*. Cape Town, South Africa: Government Printer.

Government Notice No. 201. (2014). Declaration of temporary asphalt plants as a controlled emitter and establishment of emission standards. *Government Notice No. 37461*. Cape Town, South Africa: Government Printer.

Government Notice No. 248. (2010). List of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage. *Government Gazette No. 33064*. Cape Town, South Africa: Government Printer.

Government Notice No. 356. (2016). Draft strategy to address air pollution in dense low-income settlements. *Government Gazette No. 40088*. Cape Town, South Africa: Government Printer.

Government Notice No. 486. (2012). National ambient air quality standard for particulate matter with aerodynamic diameter less than 2.5 micron metres (PM2.5). *Government Gazette No. 35463*. Cape Town, South Africa: Government Printer.

Government Notice No. 551. (2015). Amendments to the list of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage. *Government Gazette No. 38863*. Cape Town, South Africa: Government Printer.

Government Notice No. 831. (2013). Declaration of a small boiler as a controlled emitter and establishment of emission standards. *Government Gazette No. 36973*. Cape Town, South Africa: Government Printer.

Government Notice No. 886. (2017). Draft Green Transport Strategy: 2017-2050. *Government Gazette No. 41064*. Cape Town, South Africa: Government Printer.

Government Notice No. 893. (2013). List of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment including health, social conditions, economic conditions, ecological conditions or cultural heritage. *Government Gazette No. 37054*. Cape Town, South Africa: Government Printer.

Government Notice No. 919. (2013). Amendment to the 2007 national framework for air quality management in the Republic of South Africa: The 2012 national framework for air quality management in the Republic of South Africa. *Governmant Gazette No. 37078*. Cape Town, South Africa: Government Printer.

Government Notice No. 948. (2016). Draft post-2015 national energy efficiency strategy. *Government Gazette No. 40515*. Cape Town, South Africa: Government Printer.

Government Notice No. R827. (2013). National dust control regulation. *Government Gazette No. 36974*. Cape Town, South Africa: Government Printer.

Huertas, J. I., Camacho, D. I., & Huertas, M. E. (2012). Standardized emissions inventory methodology for open pit mining areas. *Environmental Science and Pollution Research, 2784*(19). doi:10.1007/s11356-012-0778-3

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Published: IGES, Japan.

Jerrett, M., Arain, A., Kanaroglou, P., & Beckerman, B. (2005). A review and evaluation of intraurban air pollution exposure models. *Journal of Exposure Analysis and Environmental Epidemiology, 15*, 185-204.

Kalenga, P. (2011). *Determination of Sulphur in South African Coal.* Johannesburg: University of Witswatersrand, Unpublished MSc.

Katsouyanni, K. (2003). Ambient air pollution and health. *British Medical Bulletin, 68*, 143-156.

Kumar, P., & Mohan, D. (2002). Photochemical smog: mechanism, ill-effects and control. *Teri Information Digest on Energy and Environment, 1*(3), 445-456.

Makonese, T., Masekameni, D. M., Annegarn, H. J., & Forbes, P. B. (2015). Influence of fire-ignition methods and stove ventilation rates on gaseous and particle emissions from residential coal braziers. *Journal of Energy in Southern Africa, 26*(4), 16-28.

Mansell, G., Fields, P., Wolf, M., Gillies, J., Barnard, W., Omary, M., & Uhl, M. (2003). Determining fugitive dust emissions from wind erosion. *12th Annual Emissions Inventory Conference*, (pp. 1-13). San Diego, California.

Maricopa. (2011). *2008 PM10 Emission Inventory*. Maricopa County, United States.

NGI. (2008). 50K Vector Data. *Environmental Potential Atlas of South Africa (ENPAT)*.

NPI. (2011). *Emission Estimation Technique Manual for Sewerage and Wastewater Treatment. Version 2.1.* Commonwealth of Australia: National Pollutant Inventory.

NPI. (2012). *Emission Estimation Technique Manual for Mining. Version 3.1.* Commonwealth of Australia: National Pollutant Inventory.

Ntziachristos , L., & Samaras, Z. (2000). *COPERT III Computer programme to calculate emissions from road transport Methodology and emission factors (Version 2.1).* Copenhagen: European Environment Agency.

Olsen, R. (2015). Emission Factors for Paved and Unpaved Haul Roads. State of Utah: Department of Environmental Quality.

Pauw, C., Fischer, T., Weston, M., Preston-whyte, F., & Badenhorst, H. (2006). *The elephant in the room: What do we know about urban wood use in South Africa? The importance of understanding domestic wood use in South Africa.*

Piketh, S., Burger, R., & Paauw, C. (2014). Ambient air pollution and emissions measurements from domestic solid fuel (coal) combustion in Mpumalanga, South Africa. *13th Quadrennial iCACGP Symposium and the 13th Quadrennial IGAC Science Conference on Atmospheric Chemistry, Brazil.*

Pope, C., & Dockery, D. (2006). Health effects of fine particulate air pollution: lines that connect. *Journal of the Air & Waste Management Association, 56*, 709-742.

Posada, F. (2017). *South Africa's New Passenger Vehicle CO2 Emissions Baseline Analysis.* Washington DC: The International Council on Clean Transportation.

Ren, F., Zhang, X., Liu, J., Sun, N., Wu, L., Li, Z., & Xu, M. (2017). A synthetic analysis of greenhouse gas emissions from manure amended agriculturals soils in China. *Scientific Reports, 8123*(7).

Sadeghpour, A., Lefever, A., Ketterings, Q., & Czymmek, K. (2016). Nitrous oxide emission from crop fields. *Agronomy Fact Sheet Series: Fact Sheet 90*. Cornell University Cooperative Extension.

SAWIC. (2008). *Treatment and Disposal.* Retrieved 2018, from South African Waste Information Centre - Department of Environmental Affairs: http://sawic.environment.gov.za/documents/352.PNG

Scapellato, M., & Lotti, M. (2007). Short-term effects of particulate matter: an inflammatory mechanism? *CRC Critical Reviews in Toxicology, 37*, 461-487.

Schwela, D. (2000). Air pollution and health in urban areas. *Reviews on Environmental Health, 15*, 13-42.

SCMEIEA. (2011). *Guidelines for Developing Emission Inventory in East Asia.* Japan: Study Committee for Methodologies of Developing Emission Inventory in East Asia. Ministry of the Environment.

Scorgie, Y., Watson, R., & Fischer, P. H. (2005). *Air Quality Management Plan for the Ekurhleni Metropolitan Municipality.* Report compiled on behalf of Ekurhleni Metropolitan Municipality, Report No. APP/04/EMM-02c.

Silva, C. M., Gonçalves, G. A., Farias, T. L., & Mendes-Lopes, J. (2006). A tank-to-wheel analysis tool for energy and emission studies in road vehicles. *Science of Total Environment, 367*, 441-447.

SIMetric. (2007). *Density, mass, SG of Liquids*. Retrieved January 29, 2018, from https://www.simetric.co.uk/si_liquids.htm

Singh, A. K., & Kumar, J. (2016). Fugitive methane emissions from Indian coal mining and handling activities: estimates, mitigation and opportunities for its utilization to generate clean energy. *Energy Procedia, 90*, 336-348.

South Africa. (1996). Constitution of the Republic of South Africa, 1996. Pretoria: Government Printer.

StatsSA. (2007). *Census of Commercial Agriculture, 2007 - Eastern Cape.* Statistics South Africa.

StatsSA. (2011). *Statistics South Africa*. Retrieved 29 January, 2018, from http://www.statssa.gov.za/

StatsSA. (2011a). *Statistics South Africa*. Retrieved 29 January, 2018, from http://www.statssa.gov.za/

StatsSA. (2016). *Community Survey.* Statistics South Africa.

Stone, A., & Bennett, K. (2001). A bulk model of emissions from south african diesel commercial vehicles. *National Association for Clean Air.*

Tyson, P. D., & Preston-Whyte, R. A. (2000). *The Weather and Atmosphere of Southern Africa.* Cape Town: Oxford University Press.

Tyson, P. D., Garstang, M., & Swap, R. (1996). Large-scale recirculation of air over southern Africa. *Journal of Applied Meteorology, 35*, 2218-2234.

Tyson, P. D., Kruger, F. J., & Louw, C. W. (1988). *Atmospheric Pollution and its Implications in th Eastern Transvaal Highveld, South African National Scientific Programmes. Report 150.* Pretoria: Foundation for Research and Development.

uMoya-NILU. (2013). *Draft Air Quality Management Plan for the Eastern Cape Province.* Output H: Air Quality Management Plan, Report No. uMN002-13.

US EPA. (1995). 1.1 Bituminous And Subbituminous Coal Combustion. In *AP-42.* United States Environmental Protection Agency.

US EPA. (1995). 1.3 Fuel Oil Combustion. In *AP-42.* United States Environmental Protection Agency.

US EPA. (1995). 11.10 Coal Cleaning. In *AP-42.* United States Environmental Protection Agency.

US EPA. (2003). *Air pollution control technology fact sheet - Cyclones. EPA-452/F-03-005.* United States Environmental Protection Agency. Retrieved 2018, from https://www3.epa.gov/ttn/catc/dir1/fcyclon.pdf

Van Basten, A., & Van Nierop, M. (2018). *Air Quality Impact Assessment: Proposed Cyferfontein 2 Clay Quarry, Waterberg District Municipality.* Gondwana Environmental Solutions: RN_1801239_ZAN.

van Nierop, P. G. (1995). *A Source Inventory of Particulate Air Pollution in the Vaal Triangle.* Johannesburg: Faculty of Engineering, University of Witswatersrand, Unpublished MSc.

Vegter, I. (2016). *Air Quality: Missing the Wood for the Trees.* South African Institute of Race Relations.

WHO. (2000). World health organization air quality guidelines for Europe. *European Series No. 91, Second ed.* Copenhagen: WHO Regional Publications.

WHO. (2005). WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. *Global Update 2005: Summary of Risk Assessment*. Copenhagen: World Health Organisation Press.

Witschi, H., & Last, J. (2001). *Toxic Responses of the Respiratory System.* New York: McGraw-Hill.

Wong, C. T. (1999). *Vehicle Emissions Project Phase II Final Report.* Pretoria: Prepared by the Energy Research Institute, University of Cape Town. Department of Minerals and Energy.

World Bank Group. (2016). Annual crop production. *Environmental, Health and Safty Guidlines*.

Wright, C., & Diab, R. (2009). Air pollution and vulnerability: solving the puzzle of prioritization. *Journal of Environmental Health, 73*, 56-64.

WWF. (2016). *Transport Emissions in South Africa.* World Wildlife Fund.

APPENDIX 1: LISTED ACTIVITY INFORMATION

Table 47: Listed Activity Information from the NAEIS

Source Name	**Province**	**District/Metro**	**Local Municipality**	**Lat**	**Long**	**Operating Hours**	**SIC NAME**	**Base Elevation (m)**	**Stack Height (m)**
National Asphalt	Eastern Cape	Chris Hani DM	Engcobo LM	-31.8486	27.0808	0	Asphalt paving of roads	6	0
AP Green Sawmills	Eastern Cape	Chris Hani DM	Enoch Mgijima LM	-31.8906	26.8967	8280	Drying of wood	9	8
East Cape Fuel	Eastern Cape	Chris Hani DM	Enoch Mgijima LM	-31.9072	26.8833	-	Petroleum bulk stations & terminals		
Source Name	**Stack Diameter (m)**	**Exit Velocity (m/s)**	**Exit Temperature (K)**	**Emission Unit Description**	**NAEIS Source Code**	**PM10 (kg/annum)**	**SO2 (kg/annum)**	**NO2 (kg/annum)**	**NOX (kg/annum)**
National Asphalt	0.6	0	0	Plant was discontinued in 2009	SA051000105		0		
AP Green Sawmills	0.45	6.1619	92	Kettle that generate hot water for wood drying	SA090500513	1936.22	0		2460.65
East Cape Fuel									
Source Name	**PM2.5 (kg/annum)**	**VOC (kg/annum)**	**Lead (kg/annum)**	**CO (kg/annum)**	**H2S (kg/annum)**	**Hg (kg/annum)**	**TSP (kg/annum)**		
National Asphalt		0					0		
AP Green Sawmills	1428.98			1336.89			2898.53		
East Cape Fuel		87.663568							

APPENDIX 2: BOILER IDENTIFICATION DETAILS

Table 48: Hospitals within Chris Hani DM phoned regarding boiler details

Municipality	Hospital Name	Contact Number	Number of Boilers	Fuel Utilized	Metric Tonnes of Coal Used per Month	Kilolitres of Oil Used per Month	Comments
Emalahleni LM	Dordrecht Hospital	045 943 1019	0				
	Glen Grey Hospital	047 878 0018	-				Phoned 10 times. No answer.
	Indwe Hospital	045 952 1030	0				
Engcobo LM	All Saints Hospital	047 548 4000	0				
Enoch Mgijima LM	Frontier Hospital	045 808 4200	2	Coal	11.7		
	Hewu Hospital	040 841 0133	0				
	Martje Venter Hospital	045 846 0053	0				1 Electric Boiler
	Queenstown Private Hospital	045 838 4110	0				
	Sterkstroom Hospital	045 966 0268	0				
Intsika Yethu LM	Cofimvaba Hospital	047 874 8000	2	Oil		8.6	1 not in use
Inxuba Yethemba LM	Cradock Hospital	048 881 2123	1	Oil		12.5	
	Wilhelm Stahl Hospital	049 842 1111	1	None			Decommissioned
Sakhisizwe LM	Cala Hospital	047 877 0069	0				
	Elliot Hospital	045 931 1321	0				

Table 49: Boarding schools within Chris Hani DM phoned regarding boiler details

Municipality	Boarding School Name	Contact Number	Number of Boilers	Fuel Utilized	Metric Tonnes of Coal Used per Month	Kilolitres of Oil Used per Month	Comments
Emalahleni LM	Dordrecht High School	045 943 1012	-				Phoned 4 times. No answer.
	Freemantle Boys' High School	079 996 5075	0				
	Indwe H School	045 952 1006	0				
Engcobo LM	Nyanga Senior Secondary School	047 548 7559	0				
Enoch Mgijima LM	Hangklip Primary School	045 839 7001	0				
	Hoerskool Hangklip	045 838 3552	0				
	Maria Louw Senior Secondary School	045 854 7626	0				
	Queen's College Boys Primary School	045 838 4400	0				
	Queenstown Girls' H School	045 839 4160	0				
	Royal Capital Education Centre	045 854 7678	0				
	Sterkstroom School	045 966 0101	-				Phoned 4 times. No answer.
	Tarkastad High School	045 846 0173	0				
Inxuba Yethemba LM	Cradock High School	048 881 2784	0				
	Cradock Preparatory School	048 881 3163	-				Phoned 4 times. No answer.
	Hoer Landbouskool Marlow	048 881 3121	0				
	Middeland Secondary School	049 842 1692	0				
	Middelburg H School	049 842 1560	0				
	Wolwevlei Primary School	049 842 1215	-				Phoned 4 times. No answer.
Sakhisizwe LM	Elliot High School	045 931 1157	0				